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The role of agronomic and fertiliser phosphorus management on pasture response

United Nations: Sustainable Development Goals

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Outline

- United Nations: Sustainable Development Goals (SDGs) and their relevance to applied/fundamental research: an example
- Importance of grasslands and phosphorus (P)
- Managing fertiliser P in grasslands
- Final comments

SDGs and their relevance to a research scientist: an example

- Soil chemistry, plant nutrition, fertiliser use
- Applied and fundamental research
- The SDGs are a vital initiative of global importance
- One part of the broader scientific community to help achieve the SDGs

United Nations: Sustainable Development Goals relevant to my research profile

- Goal 2 – End hunger, achieve food security and improved nutrition and promote sustainable agriculture

- Goal 14 – Conserve and sustainably use the oceans, seas and marine resources for sustainable development

- Goal 15 – Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

Goal 2 – Targets

- Target 2.3: By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment

- Target 2.4 By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality

UN SDGs (2016)

Goal 2 – Indicators

- Indicator 2.3.1: Volume of production per labour unit by classes of farming/pastoral/forestry enterprise size
- Indicator 2.3.2: Average income of small-scale food producers, by sex and indigenous status
- Indicator 2.4.1: Proportion of agricultural area under productive and sustainable agriculture

Goal 14 – Targets

- Target 14.1: By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution

Goal 14 – Indicators

- Indicator 14.1.1: Index of coastal eutrophication and floating plastic debris density

Goal 15 – Targets

- Target 15.3: By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world

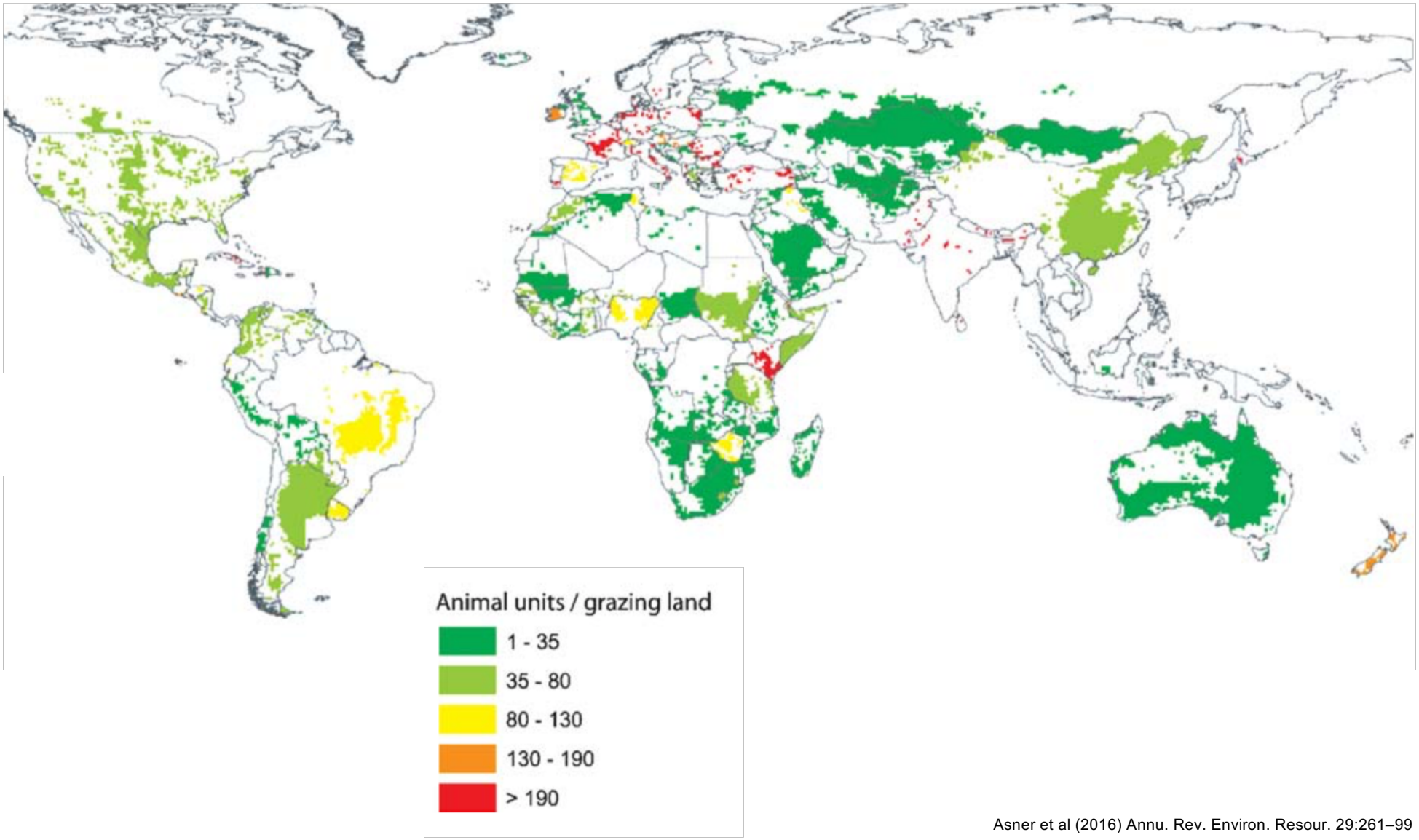
Goal 15 – Indicators

- Indicator 15.3.1: Proportion of land that is degraded over total land area

Managed grasslands

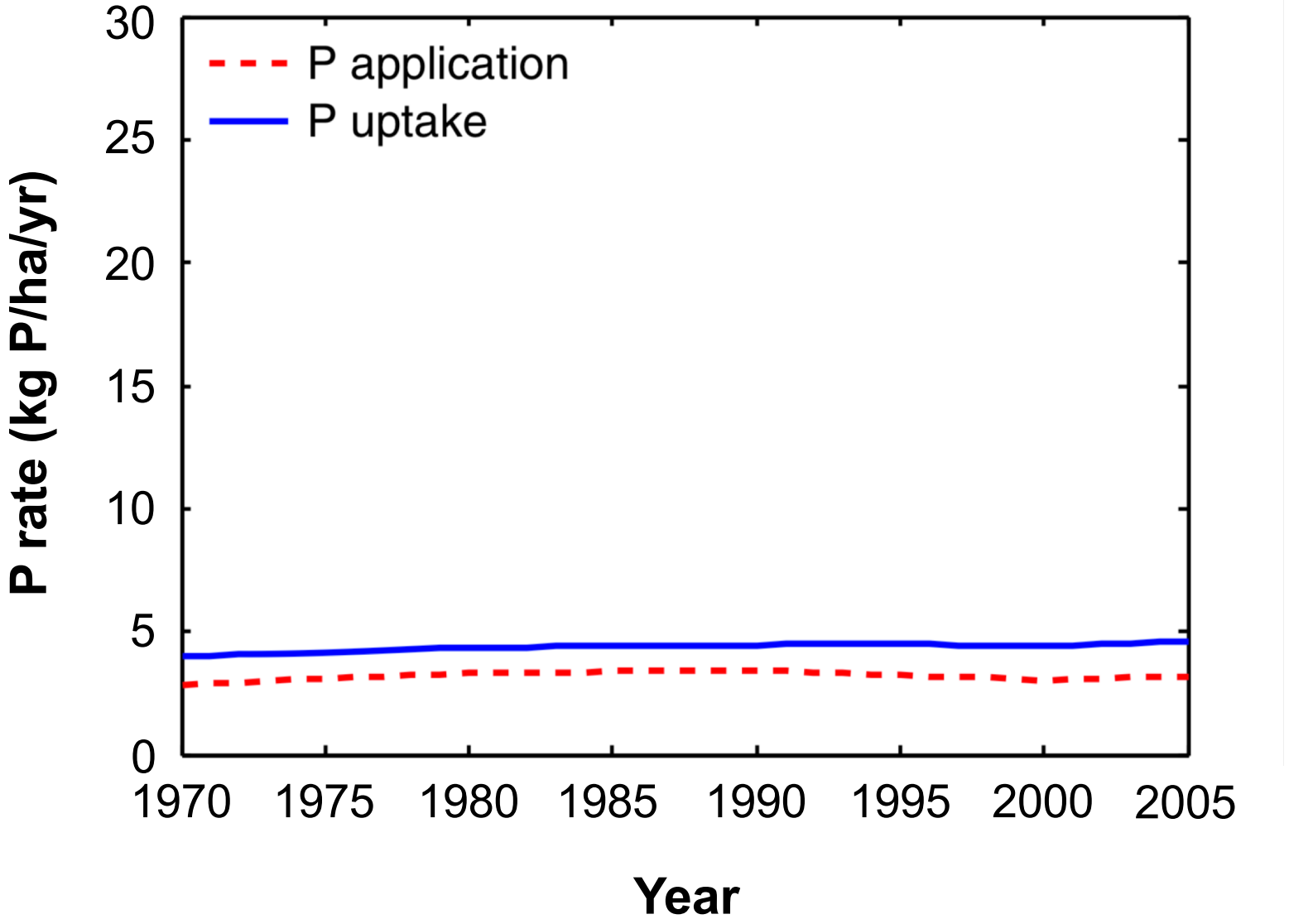
- Permanent grassland under grazing accounts for about one quarter of the world's ice-free landmass
- Grasslands are an important use of land for animal production, i.e. for food and fibre
- Phosphorus is typically the most limiting nutrient affecting pasture growth

Distribution of managed grasslands



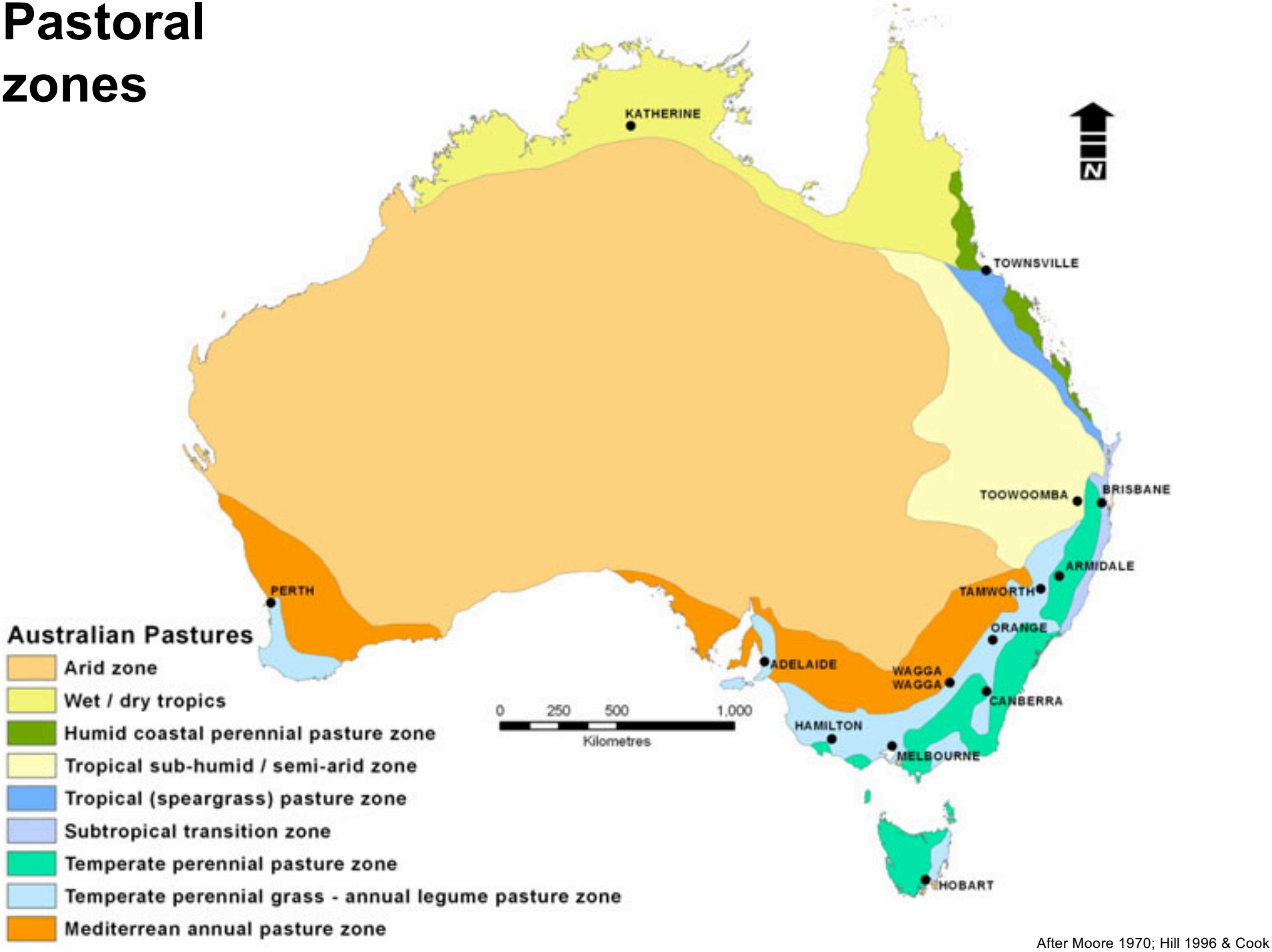
Asner et al (2016) Annu. Rev. Environ. Resour. 29:261–99

Global P budget of grasslands

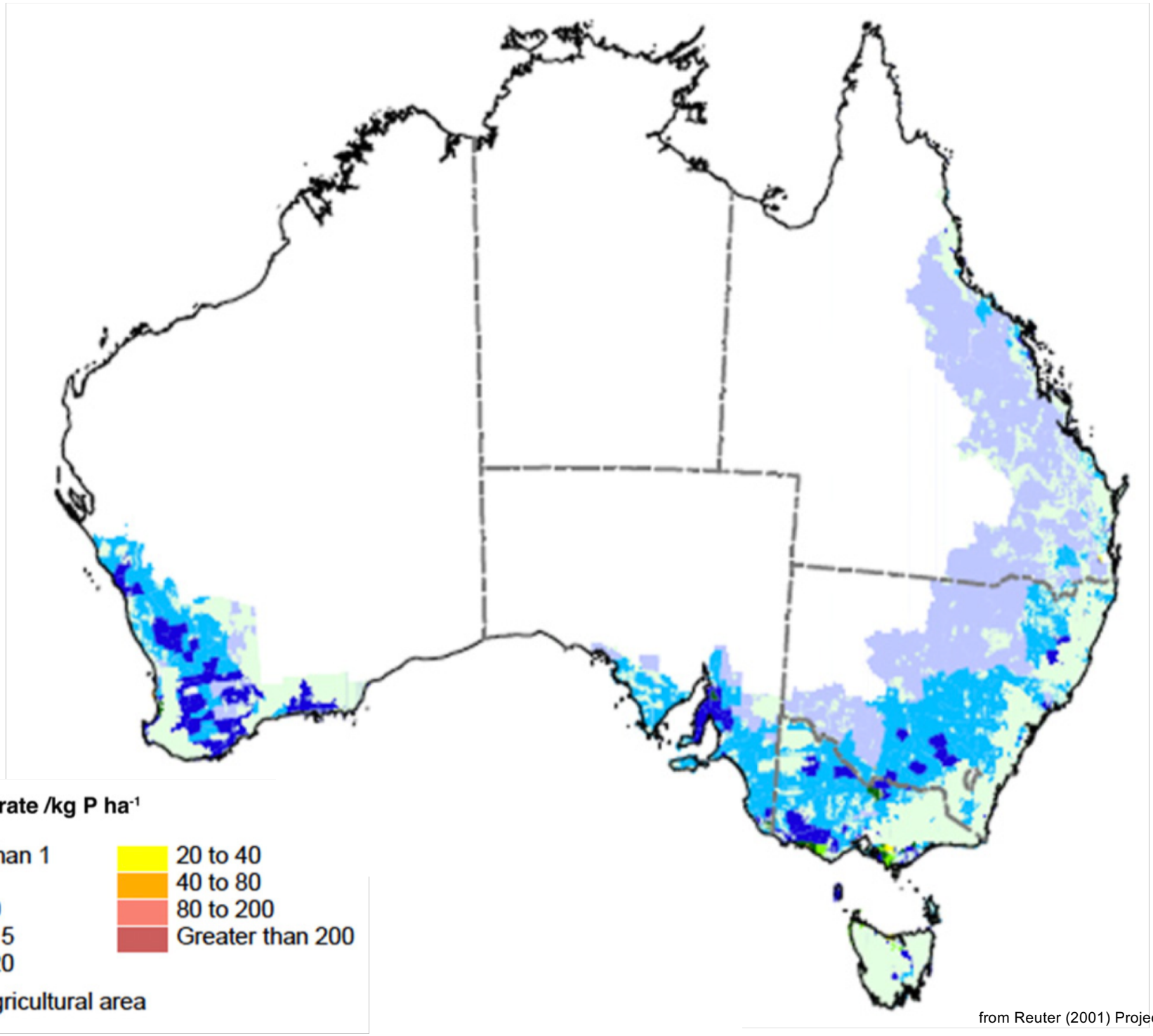


Sattari et al (2016) Nat. Comm. 7:10696

Pastoral zones



After Moore 1970; Hill 1996 & Cook

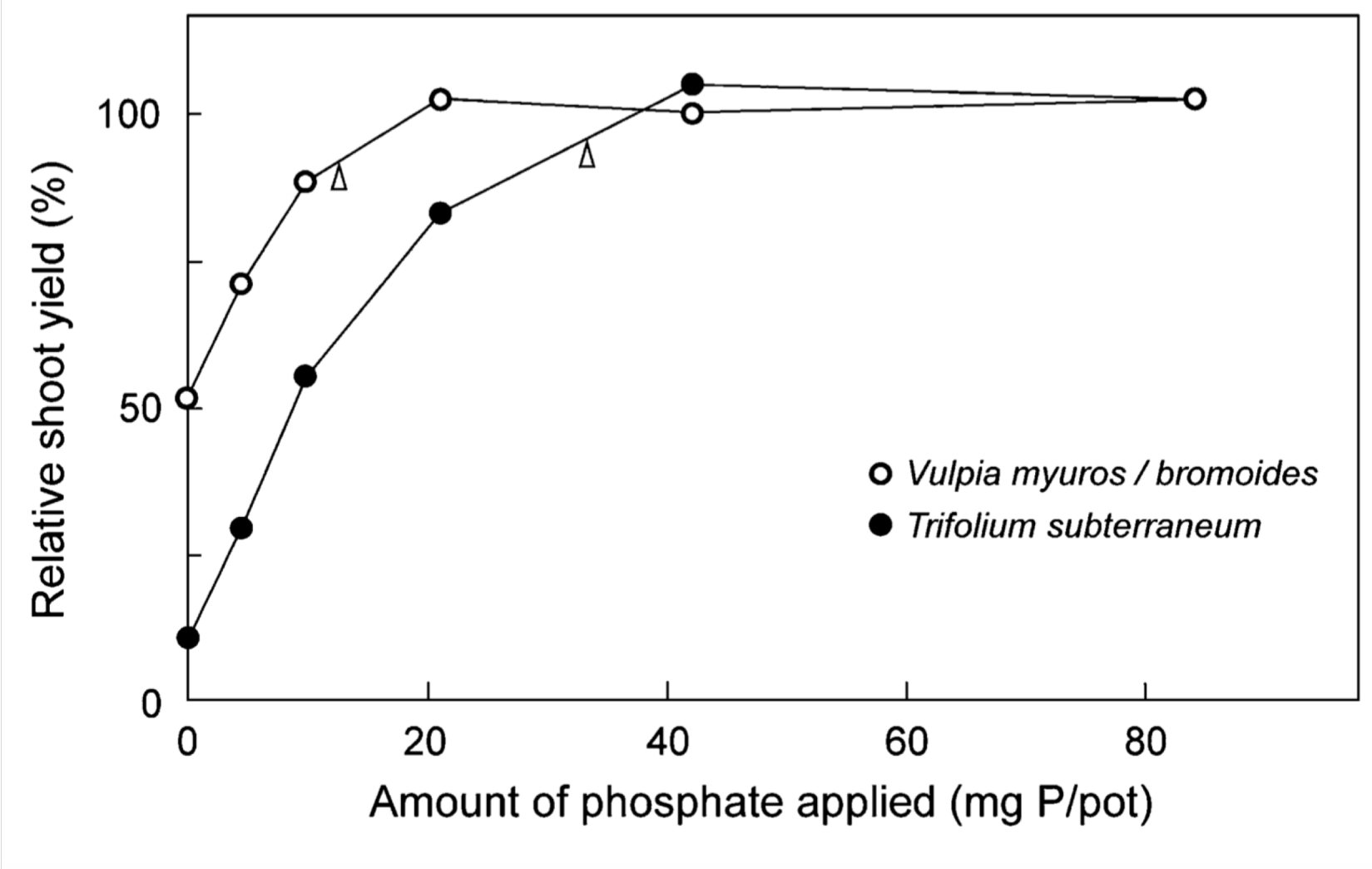


from Reuter (2001) Project 5.4D

Phosphorus and pasture production

- In Australia, the ‘sub and super’ philosophy has resulted in rapid and sustained improvements in productivity
- The land area of the high rainfall zone (HRZ) in the south-eastern region is ~ 8 million hectares (3.2 million acres)
- Some surveys indicate at least half of the sampled fields have a soil P fertility below the agronomic optimum

External P requirements differ between pastures species



from Simpson et al (2011) Plant Soil 349(1-2):89-120

Phosphorus management

- In general, between 9 – 12 kg P ha^{-1} yr^{-1} is applied to leguminous pastures of the HRZ
- Early-season (autumn) application to the soil surface
- Single superphosphate is the main type of fertiliser P added to pastures
- It is assumed that much of the fertiliser P is rapidly transformed to ‘slowly-available’ forms of soil
  - Estimates of < 20 % recovery of fertiliser P by pastures

Fate of fertiliser P over a single growing season

- **Aim:** Investigate the fate of fertiliser P in components of the pasture system as affected by fertiliser management under field conditions

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

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

- Fertiliser P was added to pastures to supply 20 kg P/ha as ^{33}P-labelled SSP granules

- Ginninderra (five harvests) and Inman Valley (four harvests)

Treatments

- Experiment 1, Ginninderra and Inman Valley – placement and timing:
  1. Non-fertilised (control)
  2. A surface application of SSP at early-season (autumn)
  3. A surface application of SSP at mid-season (spring)
  4. A 'deep' application (6 cm below soil surface) of SSP at early-season
- Experiment 2, Ginninderra – initial soil P fertility:
  1. Non-fertilised (control)
  2. A surface application of ^{33}P-labelled SSP at early-season (autumn)

Field site location	pH_w (1:5)	Total C (%)	P sorption index (PBI)	$NaHCO_3$-P (mg/kg)
Ginninderra P0	5.2	2.0	50	18
Ginninderra P1	5.2	2.3	44	36
Ginninderra P2	5.1	2.6	44	60
Inman Valley	5.7	1.6	19	14

Ginninderra field site

Experiment 1: Clover shoots (> 0 cm)

Field site	Treatments		Cumulative biomass (t DM/ha)	Cumulative P uptake (kg P/ha)	Recovery of fertiliser P (as a % of applied)
	Timing of fertiliser P	Placement of fertiliser P			
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

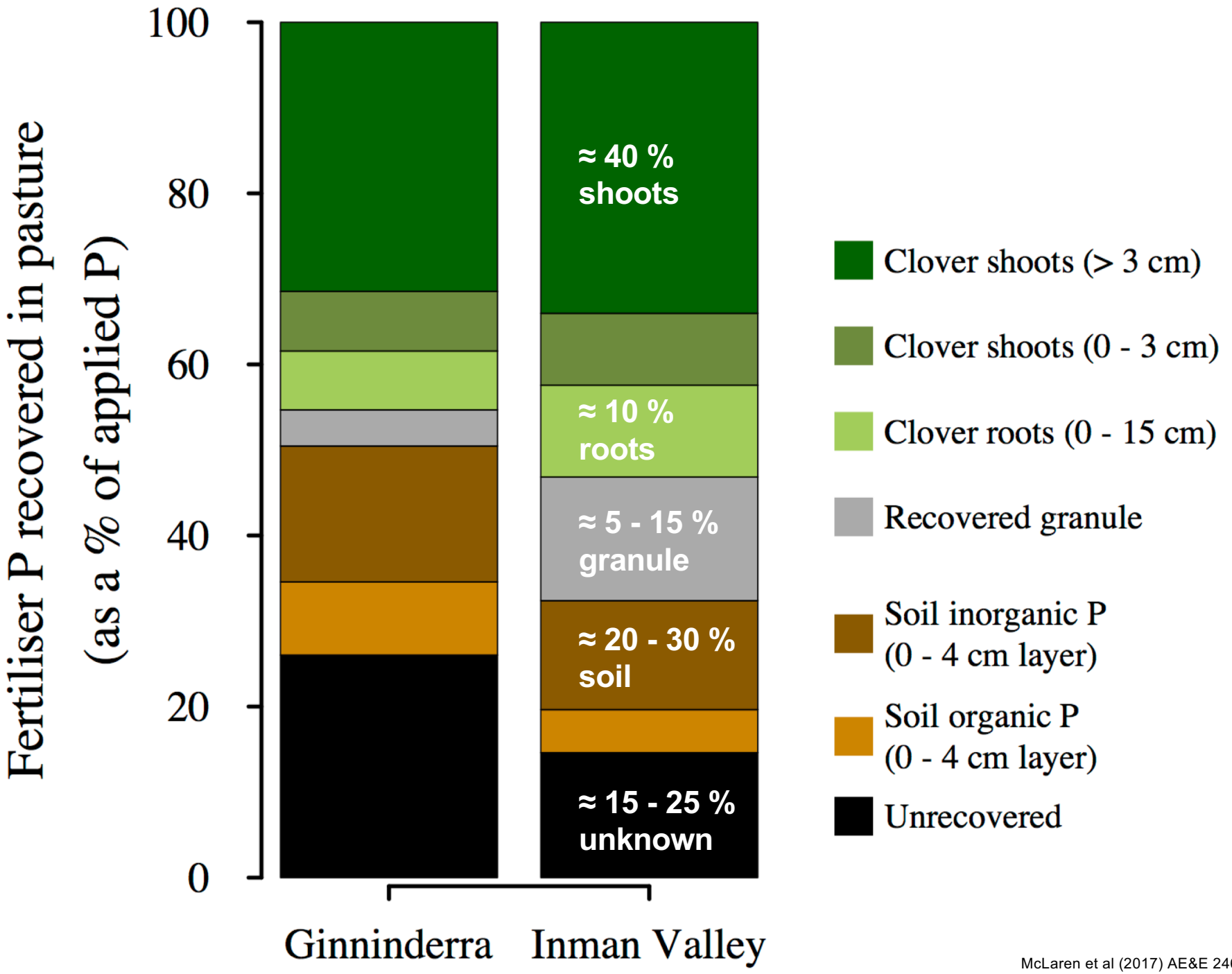
McLaren et al (2017) AE&E 246:144-156

Experiment 2: Clover shoots (> 0 cm)

Level of soil P fertility	Cumulative biomass (t DM/ha)	Cumulative P uptake (kg P/ha)	Recovery of fertiliser P (as a % of applied)
P0	15.8 (0.2)	20.8 (3.2)	41.6 (0.5)
P1	18.0 (0.4)	41.1 (3.1)	45.5 (1.0)
P2	20.5 (1.4)	51.9 (3.8)	42.5 (0.9)

Values in parentheses are standard errors

McLaren et al (2017) AE&E 246:144-156



McLaren et al (2017) AE&E 246:144-156

Research outcomes and SDGs

- Target 2.3: By 2030, double the agricultural productivity…
  - Application of fertiliser P improves pasture growth of grasslands
  - Pasture growth was generally highest for early-season applications to the soil surface at optimum soil P fertility
- Target 2.4 By 2030, ensure sustainable food production systems… and that progressively improve land and soil quality
  - Fertiliser P use efficiency was generally the highest for early-season applications to the soil surface at optimum soil P fertility
  - Fertilisation at depth could be an option to reduce the risk of surface drought

Fate of fertiliser P over the long-term

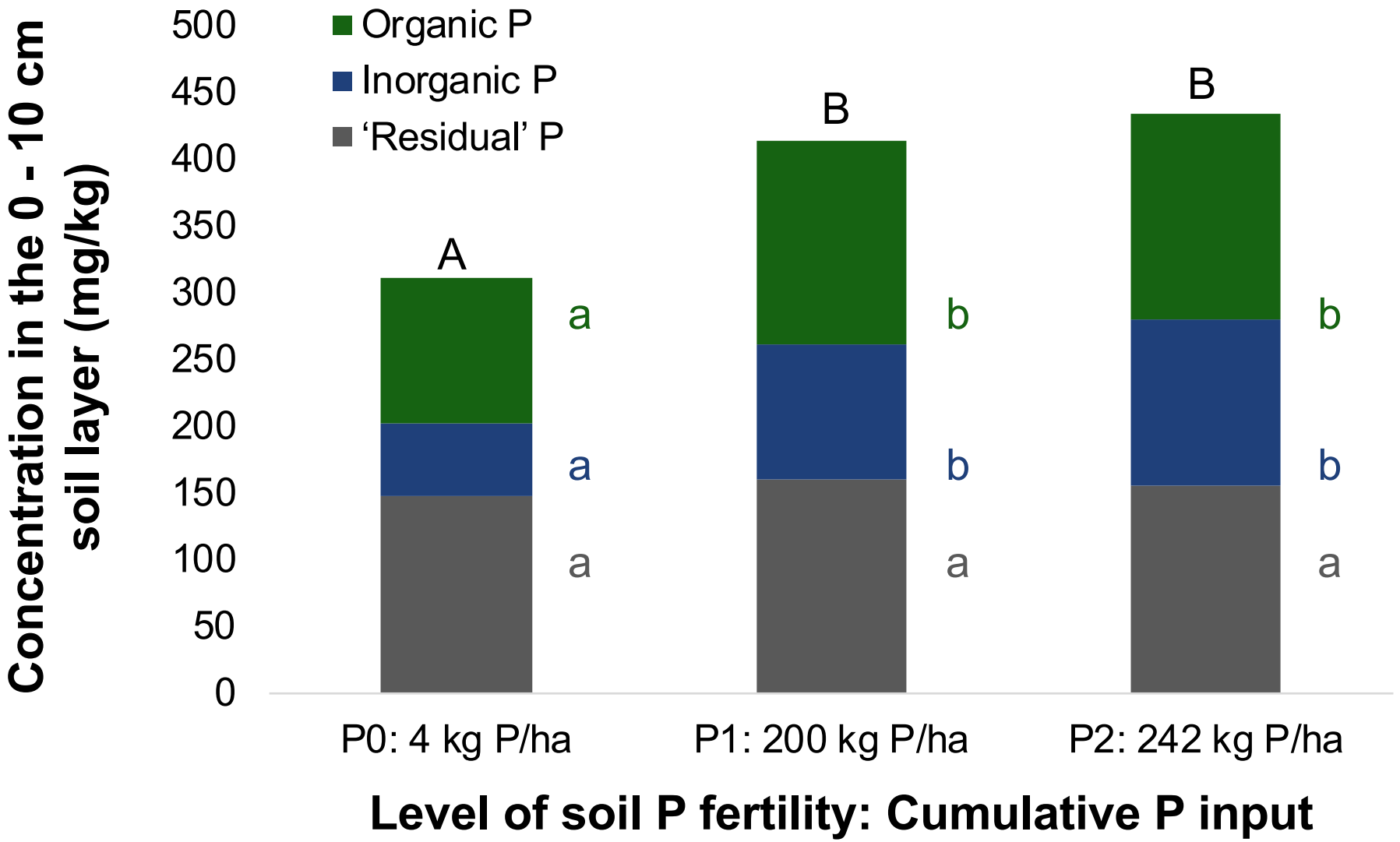
- **Aim 1:** Identify the forms of soil P that accumulate in pastures and estimate their apparent recovery

- Field experiment established in 1994 on an acidic Luvisol

- After 13 years of fertilisation:
  - 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

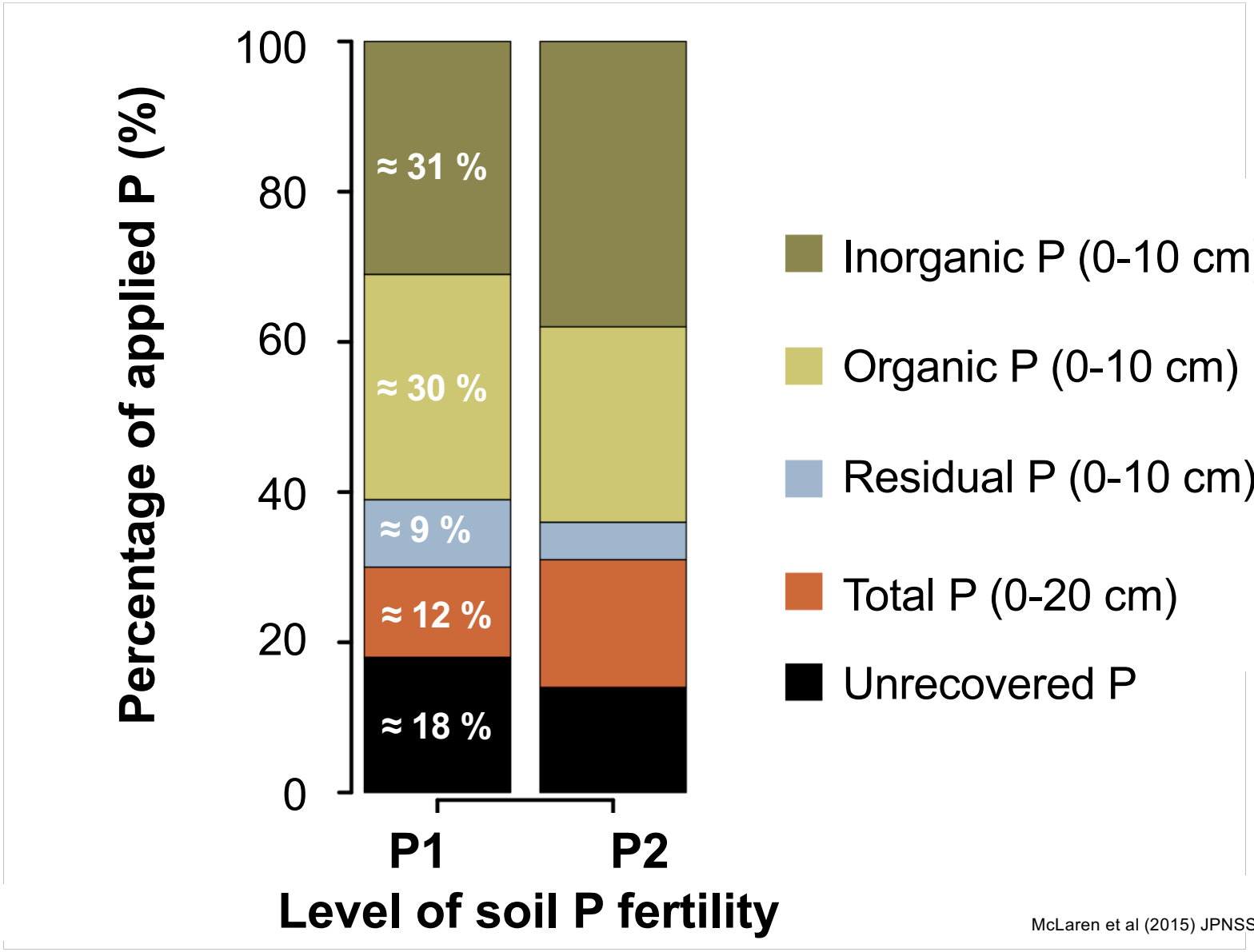
- Sequential chemical fractionation, NaOH-EDTA and NMR

Ginninderra long-term (13 years) field experiment



McLaren et al (2015) JPNSS 178(4):543-554

Apparent recovery of fertiliser P in soil



McLaren et al (2015) JPNSS 178(4):543-554

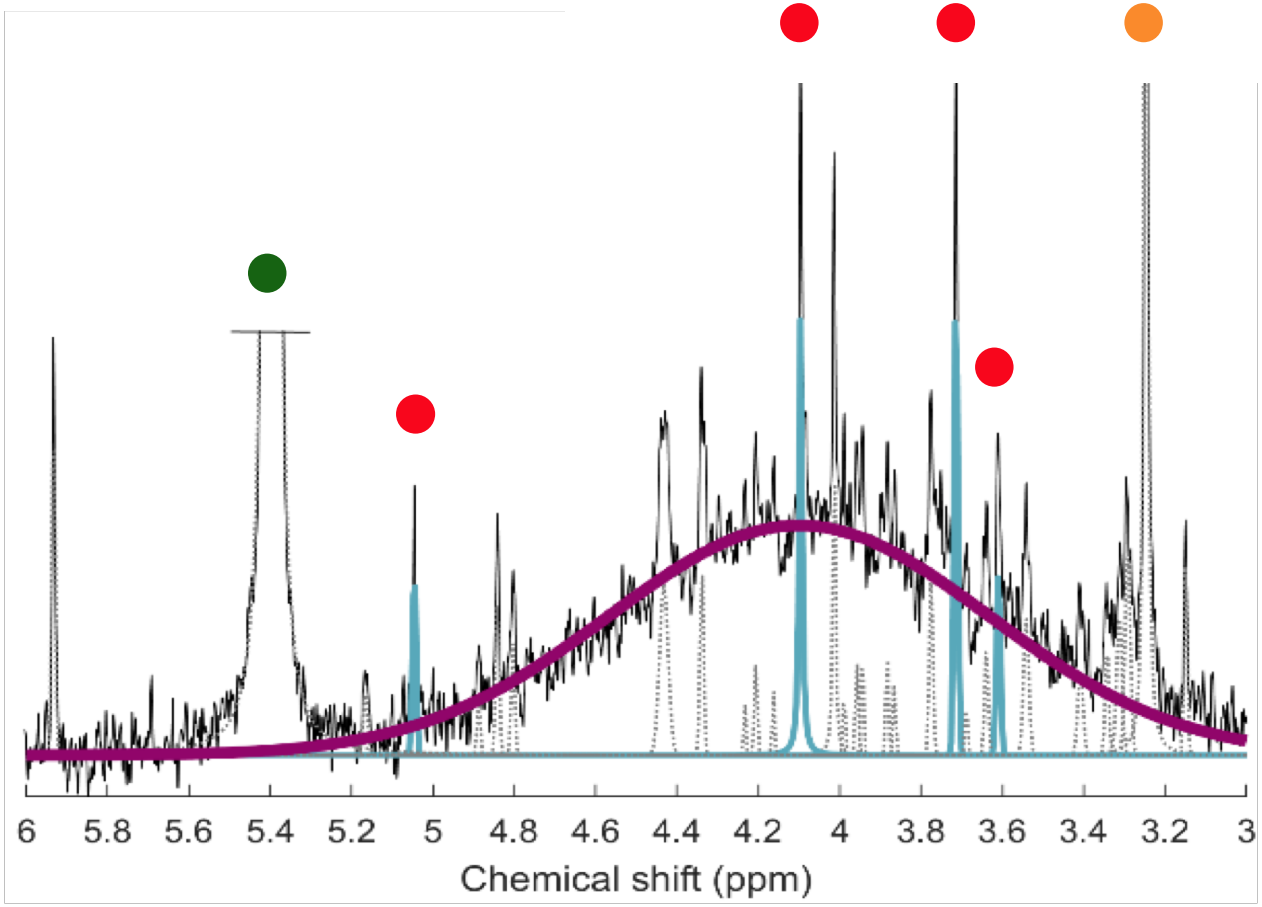
Chemical nature of organic P in soil

- In general, the largest pool of organic P in soil extracts is that of a broad signal in the phosphomonoester region of a NMR spectrum

= orthophosphate

= *myo*-IHP

= *scyllo*-IHP



Chemical nature of organic P in fertilised soils (0-10 cm layer)

Level of soil P fertility	Phosphomonoesters					DNA
	Total	Broad	IHP	α- & β-Gly.	RNA mono.	
P0	66 a	46 a	9 a	7 a	4 a	4 a
P1	90 b	64 b	11 a	11 a	5 a	8 b
P2	83 b	60 b	10 a	10 a	3 a	6 b

Concentrations (mg/kg) of soil P in NaOH-EDTA extracts: solution ^{31}P NMR analysis

McLaren et al (2017) JPNSS 180(1):27-38

Research outcomes and SDGs

- Target 2.4 By 2030, ensure sustainable food production systems… and that progressively improve land and soil quality

  - A large proportion of the fertiliser P remains in the soil, which could potentially be accessed by pastures

  - Fertilisation increased concentrations of organic P associated with the soil organic matter

- Target 14.1: By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from… nutrient pollution

  - Fertilisation above the optimum accumulated largely in inorganic forms of soil P, which has the risk of transfer to aquatic ecosystems

Research outcomes and SDGs (cont.)

- Target 15.3: By 2030, combat desertification, restore degraded land and soil…

  - Fertilisation of P to soil increased concentrations of organic P associated with soil organic matter

Realisation of SDGs

- Indicators can only be reached if changes to current operations have been modified

- Gain an understanding of the relevance of your research beyond your experimental area

- Communicate research findings with stakeholders (e.g. primary producers)
  - Workshops
  - Newspaper
  - Social media
  - Publications

Final comments

- It is essential that we work together in helping to achieve the SDGs
- Grasslands represent a major use of land that have great potential for increased productivity
- ‘Best practice’ agronomic and P management of grasslands can lead to improved productivity, fertiliser efficiency, and soil quality
- Working with stakeholders (e.g. primary producers) is essential to help promote action that leads to quantifiable changes

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