How does biodiversity benefit agriculture?

Jim Radford
Research Centre for Future Landscapes
La Trobe University

Presentation to Goulburn Broken CMA, October 20, 2020

What is biodiversity?

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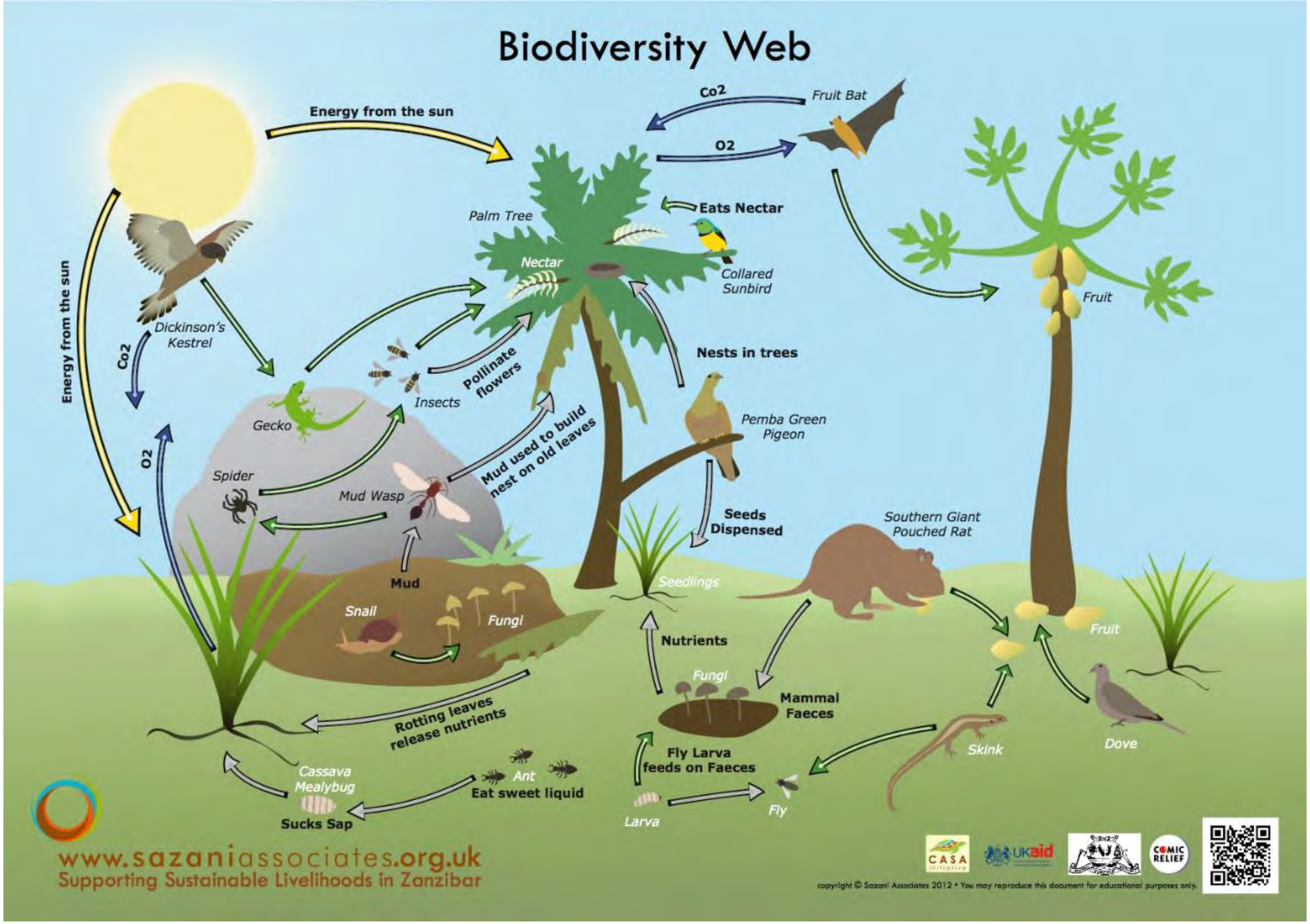
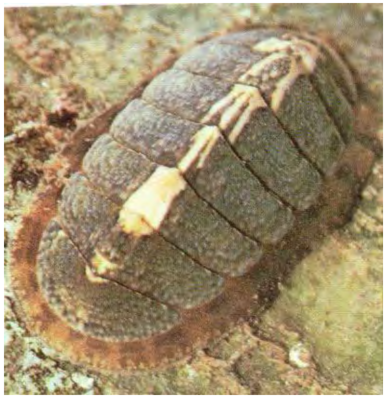


What is biodiversity?



- Biodiversity – is the diversity of all forms of living organisms. It includes diversity within and among species (including genetic diversity) and **diversity within and among ecosystems**.

What are ecological processes?

Biotic processes – interactions between individual organisms or species (e.g. predation, herbivory, competition, parasitism, mutualisms) and movement of organisms that facilitate processes

What are ecological processes?

Abiotic processes – processes associated with the physical environment, such as climatic processes, weathering, formation of biophysical habitats, hydrological processes (groundwater and surface water)

What are ecological processes?

Biotic-abiotic processes – interactions between organisms and physical environment (e.g. photosynthesis, disturbance regimes, ecosystem engineers)

Photo credit:
Birchip Cropping Group

What are ecological processes?

- Ecosystem services – ecological processes that benefit people
  - crop production, timber, fibre and meat production
  - pollination, seed dispersal, pest control, waste decomposition
  - nitrogen-fixation, nutrient cycling, carbon sequestration

Provisioning Services

Products obtained from ecosystems

- Food
- Fresh water
- Fuelwood
- Fiber
- Biochemicals
- Genetic resources

Regulating Services

Benefits obtained from regulation of ecosystem processes

- Climate regulation
- Disease regulation
- Water regulation
- Water purification
- Pollination

Cultural Services

Nonmaterial benefits obtained from ecosystems

- Spiritual and religious
- Recreation and ecotourism
- Aesthetic
- Inspirational
- Educational
- Sense of place
- Cultural heritage

Supporting Services

Services necessary for the production of all other ecosystem services

- Soil formation
- Nutrient cycling
- Primary production

Millennium Ecosystem Assessment (2005)

Biodiversity on farms: a three-sided coin?

How does biodiversity benefit agriculture?

- Ecosystem services
- Nature @ Work
- Private benefit

How can farming minimise impacts on biodiversity?

- Regenerative agriculture
- Sustainable agriculture
- Public & private benefit

How can farmers increase biodiversity on their farms?

- Wildlife-friendly farming
- Habitat restoration
- Public benefit

> ➢ **Increased production / profitability**
> ➢ **Reduced environmental impact**
> ➢ **Maintain or enhance biodiversity**

Biodiversity on farms

Vegetation
- Remnants
- Planted
  - Shelterbelts
  - Blocks

Microbes
- Bacteria
- Fungi

Invertebrates

Vertebrates

Recent reviews

Austral Entomology

Austral Entomology (2018) **57**, 194–206

Review

Ecosystem service of biological pest control in Australia: the role of non-crop habitats within landscapes

Vesna Gagic,* Cate Paull and Nancy A Schellhorn

CSIRO, GPO Box 2583, Brisbane, QLD 4001, Australia.

CSIRO PUBLISHING

Crop & Pasture Science, 2018, **69**, 785–796

https://doi.org/10.1071/CP17242

Rev

Impacts of windbreak shelter on crop and livestock production

T. P. Baker[A,D], *M. T. Moroni*[B], *D. S. Mendham*[C], *R. Smith*[B], *and M. A. Hunt*[A]

[A]ARC Centre for Forest Value & School of Natural Sciences, University of Tasmania, Sandy Bay, Tas. 7001, Australia.

[B]Private Forests Tasmania, 30 Patrick Street, Hobart, Tas. 7000, Australia.

[C]CSIRO Land and Water, 15 College Road, Sandy Bay, Tas. 7001, Australia.

[D]Corresponding author. Email: tpbaker@utas.edu.au

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

ELSEVIER

Review

Trees on farms to support natural capital: An evidence-based review for grazed dairy systems

Jacqueline R. England[a,*], Anthony P. O'Grady[b], Aysha Fleming[c], Zara Marais[d], Daniel Mendham[b]

[a] *CSIRO Land and Water, Private Bag 10, Clayton South, VIC 3169, Australia*

[b] *CSIRO Land and Water, Private Bag 12, Hobart, TAS 7001, Australia*

[c] *CSIRO Land and Water, Hobart, TAS 7000, Australia*

[d] *ARC Centre for Forest Value, School of Natural Sciences, University of Tasmania, Sandy Bay, TAS 7001, Australia*

Journal of Applied Ecology

RESEARCH ARTICLE

Ecological, biophysical and production effects of incorporating rest into grazing regimes: A global meta-analysis

Sarah E. McDonald[1,2] | Rachel Lawrence[1] | Liam Kendall[1] | Romina Rader[1]

Productivity benefits of shelterbelts

- moderating microclimate – reducing heat stress through shading; reducing wind-chill through reducing wind speed;
- reducing evapotranspiration and increasing soil moisture through reducing wind speed and temperature in the 'sheltered zone' (up to 20 times height);
- reducing soil loss and spray drift by reducing wind speed;
- increasing competition for water, nutrients and light in the competition zone (1-3 times height of the shelterbelt);
- harbouring predators (invertebrates and vertebrates) of crop and pasture pests (i.e. beneficial insects, natural enemies, biological control);
- harbouring consumers (pests) of crops, pasture and stock;
- harbouring pollinators of crops and vines – wasps, bees, birds;
- harbouring consumers of waste products (invertebrates, dung beetles, raptors, scavengers); and
- harbouring decomposers (for nutrient-cycling) (invertebrates, dung beetles, worms).

Pasture and crop growth (from Baker et al. 2018)

Publication	Windbreak type	Location	Result	Conclusion
Sturrock (1981)	Various	New Zealand	+35%	Shelterbelt standards are currently held back by lack of information
Kort (1988)	Tree	Global[A]	–8 – +203%	94 out of 97 shelterbelts increased crop yield but varied with species and environment
Bicknell (1991)[B]	Tree	Australia (WA)	0–30% increase	Increase was species dependent. Lupins 27–20%, oats 0–10%
Burke (1991)[B]	Tree	Australia (Vic.)	+0 – 45% (sheltered zone), –31 – –49% (competition zone)	Increased yields observed varied with species and direction of windbreak
Hawke and Tombleson (1993)	Trees	New Zealand	Overall decrease	Paddock level decrease but 15% increase at peak shelter
Sun and Dickinson (1994)	Tree	Australia	+6.7% yield, +11% quality	Reduction in competition zone but increase in sheltered zone resulted in overall paddock increase
Bird (1998)	Tree	Global	+12 – 60%[C]	Impact hard to detect as effect size is small and variability between and within paddocks overwhelms response
Nuberg (1998)	Various	Global	+0 – 47%	26 out of 31 studies showed yield increases 3 decreased but only measured competition zone. Results highly temporally and spatially variable
Bird *et al.* (2002*a*)	Tree	Australia (Vic.)	–28% (competition zone)	Significant reduction in competition zone (0–1TH) but no difference in sheltered zone
Bird *et al.* (2002*b*)	Artificial	Australia (Vic.)	+8 – 10% annually	Small but consistent increase in pasture in sheltered plots. Trend reversed in wet conditions
Nuberg *et al.* (2002)	Tree	Australia (SA)	+0 – 81%	Largest increase in the dry season
Sudmeyer *et al.* (2002*a*)	Tree	Australia (WA)	+0 – 25%	Increase only observed in sites with high winds
(Sudmeyer and Scott 2002)	Tree	Australia (WA)	–2.8%	Consistent decrease in competition zone and only small increase in sheltered zone, although increased in dry year
Cleugh *et al.* (2002)	Various	Australia	No response or small increase	Overall yield results are small but benefits were enhanced in dry years and when wind was a limiting factor
Oliver *et al.* (2005)	Tree	Australia	–24 – +17%	Across all paddocks 4 out of 21 had a net positive yield increase, but varied with year
Sudmeyer and Speijers (2007)	Artificial	Australia	Yield decrease within 1.5–3 shelter heights	Shading has a negative impact on crop yield. Variable between species
Bennell and Verbyla (2008)	Tree	Australia	+0 – 19%	Showed strong spatial, temporal and species variation with effects stronger in dry and windy years

[A]Reported results from temperate systems only.
[B]Results derived from (Nuberg 1998).
[C]Results exclude studies previously reported by Kort (1988).

Livestock mortality (from Baker et al. 2018)

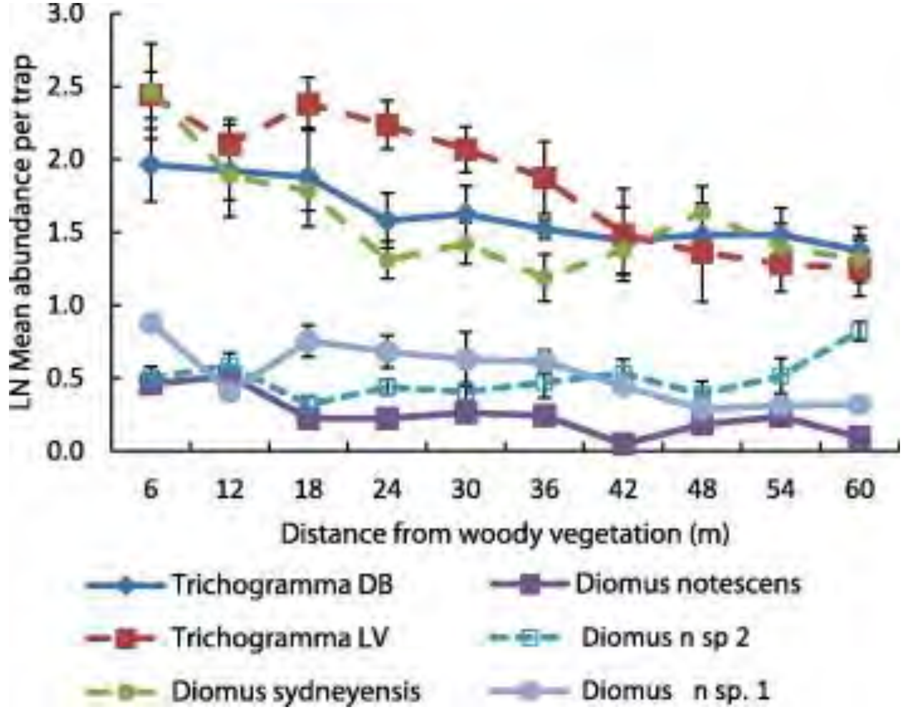
Publication	Windbreak type	Study	Location	Conclusions
Miller (1968)	Artificial	Sheep	New Zealand	No response in live-weight, although lambs utilised shelter
Egan *et al*. (1972)	Artificial	Sheep	Australia (Victoria)	13% increase in early survival. Benefit driven by wind
Lynch and Alexander (1977)	Grass and artificial	Sheep	Australia (NSW)	50% reduction in mortality. Shelter used more in inclement weather
Alexander *et al*. (1980)	Grass	Sheep	Australia (NSW)	10–32% survival increase. Driven by wind velocity
Lynch *et al*. (1980*b*)	Grass	Sheep	Australia (NSW)	50% reduction in mortality
Bird *et al*. (1984)	Trees	Sheep	Australia	Shelter reduces lamb mortality by up to 50%
Gregory (1995)	Trees	Livestock	New Zealand	Shelter reduces mortality but effect is most prevalent in young lambs and shorn sheep in inclement weather
Pollard (2006)	Various	Sheep	New Zealand, Australia	Wind shelter reduced mortality by 3–13% of single lambs, and 14–37% of twins
Fisher (2007)	Various	Livestock	New Zealand	Shelter must be provided in situations where the animal would use it
Hinch and Brien (2014)	Various	Sheep	Australia	Overall shelter reduces mortality rates but more research is required

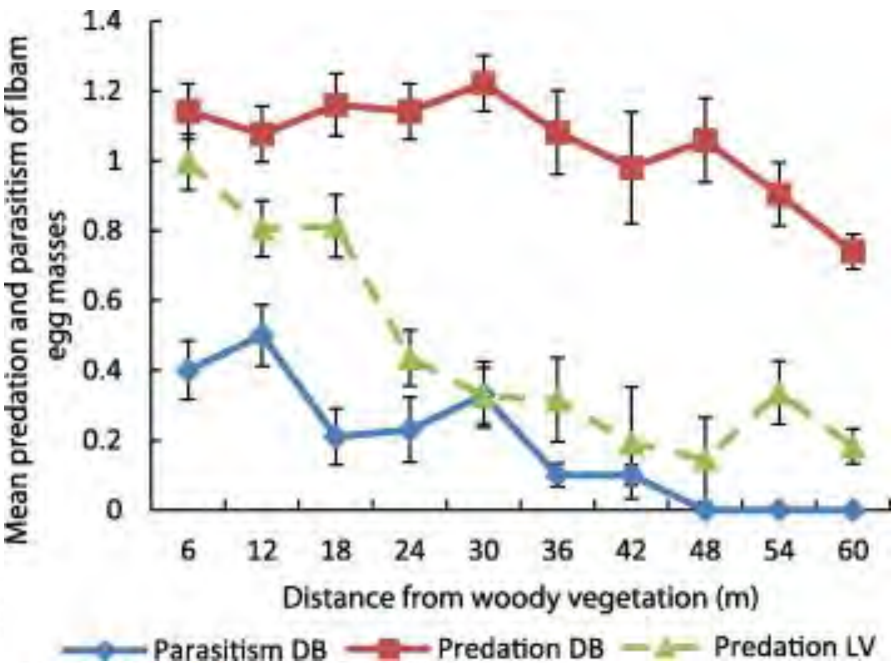
Livestock productivity (from Baker et al. 2018)

Publication	Windbreak type	Animal	Location	Results	Conclusions
Gregory (1995)	Tree	Sheep, Cattle	Australia, New Zealand	NA (Review)	Shelter minimises the weather conditions which reduce productivity. Benefits may be restricted to extreme conditions. Much of the evidence is anecdotal
Bird (2003)	Various	Dairy Cows	Global	NA (Review)	Extreme environmental conditions reduce productivity. Shelter can limit losses but evidence is not conclusive in southern Australia
Alexander and Lynch (1976)	Grass	Sheep	NSW	Lambs with shelter 12 g heavier at 21 days	Shelter protects lambs and gives them early growth advantage
Lynch and Donnelly (1980)	Artificial	Sheep	NSW	Shelter increased wool produced per day	Increase in productivity is linked to increased pasture growth that was observed
Lynch *et al.* (1980*a*)	Artificial	Sheep	NSW	Energy intake was 15–21% higher with shelter	Energy intake is linked to live-weight and wool production
Pollard and Littlejohn (1999)	Artificial	Sheep	New Zealand	No productivity differences	Lack of difference between shelter and no-shelter may be due to the lack of extreme conditions

Case studies

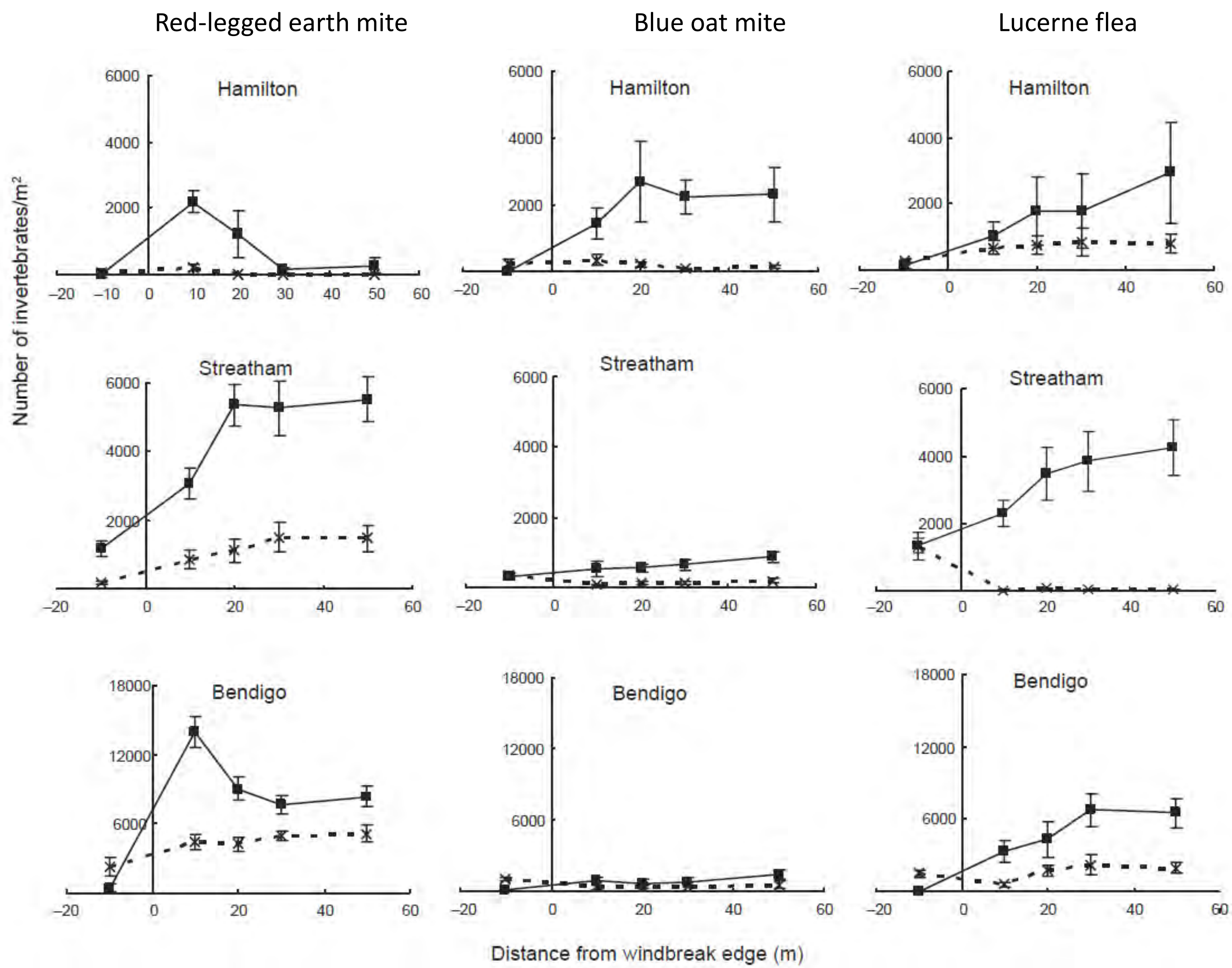
Predation and parasitism of Light Brown Moths in vineyards





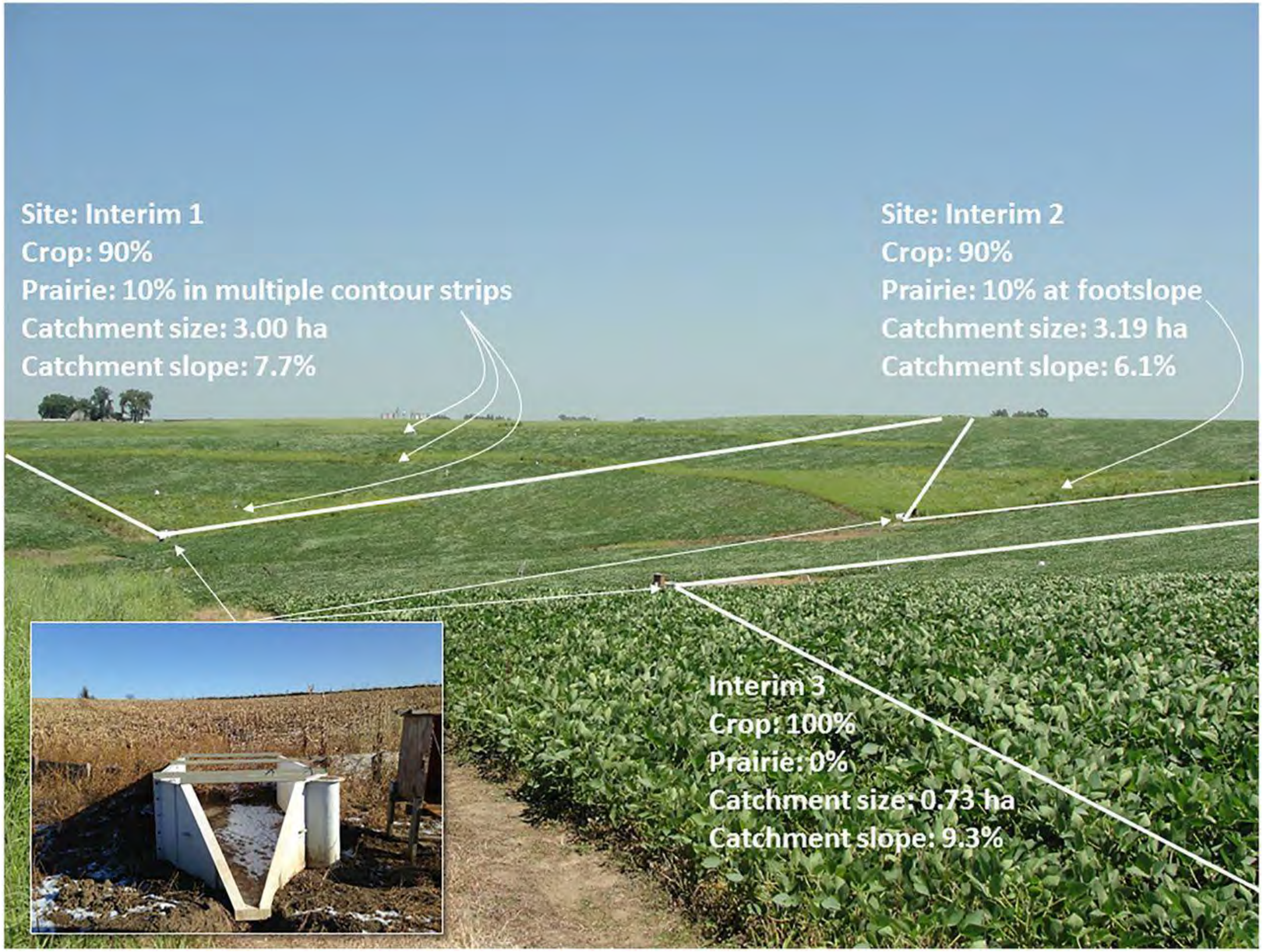
Thomson & Hoffmann (2013) Spatial scale of benefits from adjacent woody vegetation on natural enemies within vineyards. *Biological Control*, **64**, 57-65. https://doi.org/10.1016/j.biocontrol.2012.09.019.

Complex shelterbelts can reduce pasture pests



Tsitsilas et al. (2006) Shelterbelts in agricultural landscapes suppress invertebrate pests. *Aust J Exp Agric.* 46, 1379-1388

Priare (grassland) strips in corn and soy crops (Iowa)



Lisa A. Schulte et al. PNAS 2017;114:42:11247-11252

Priare (grassland) strips in corn and soy crops (Iowa)

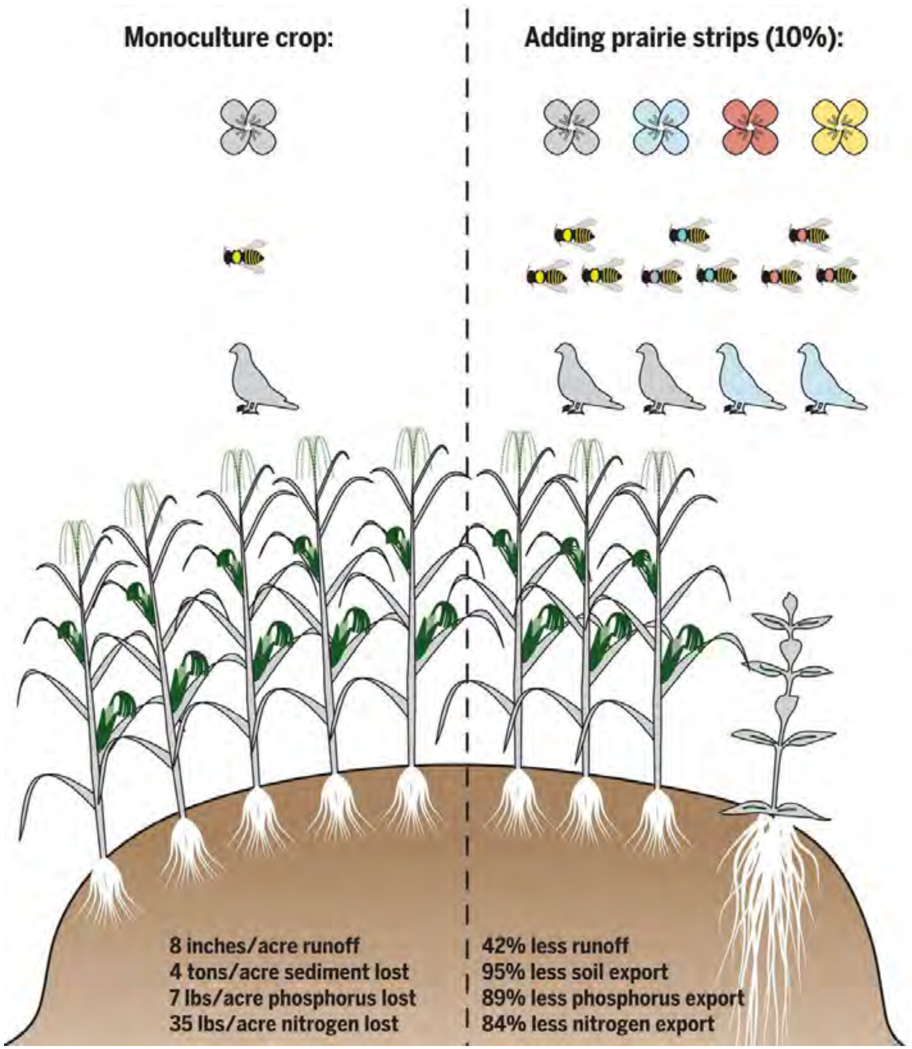
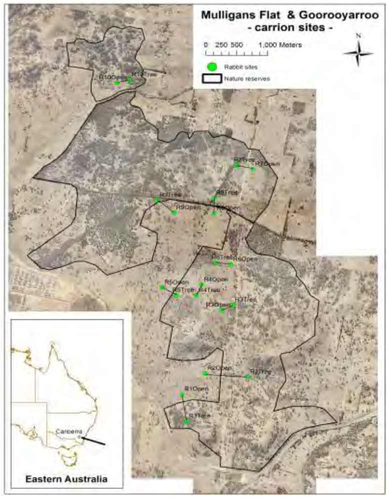
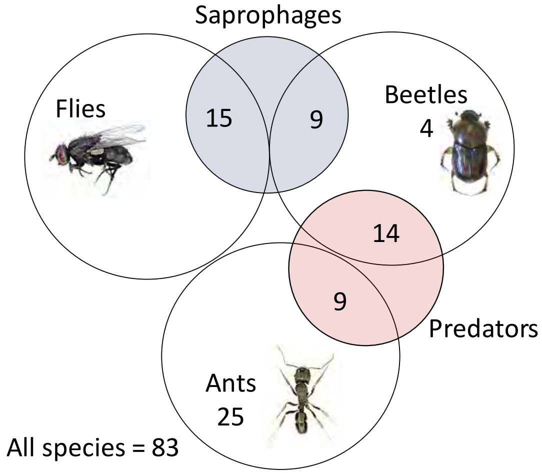
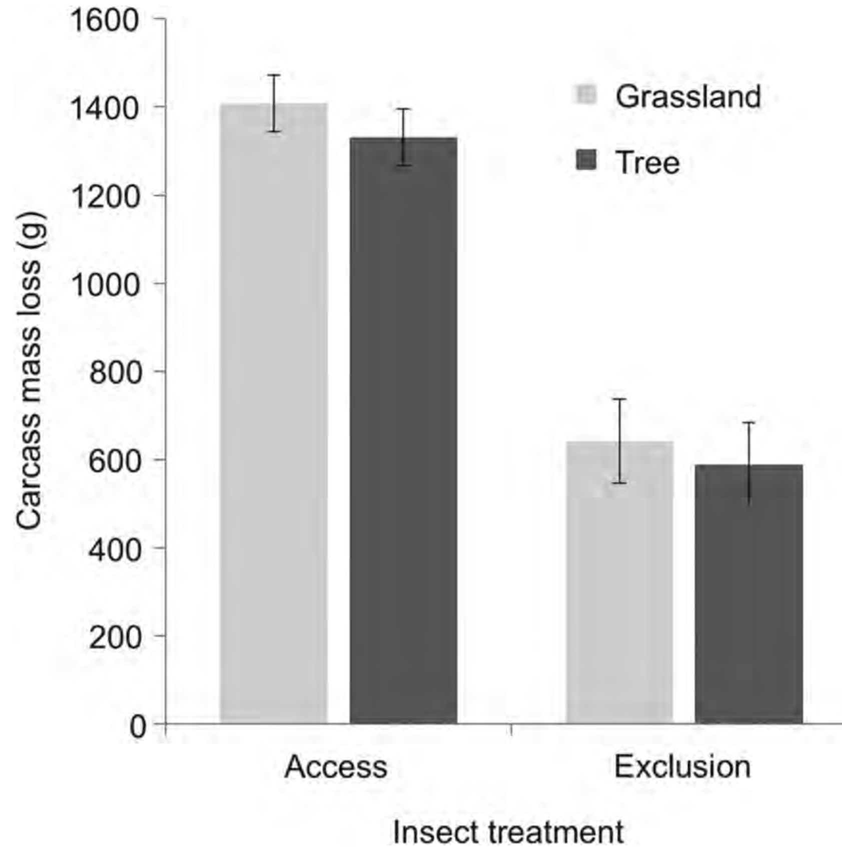


Figure from: Kremen & Merenlender (2018) *Science,* **362**:6020 adapted from:
Shulte et al. (2017) *Proc Natl Acad Sci USA*, **114**, 11247-11252.

Decomposition of carcasses by invertebrates

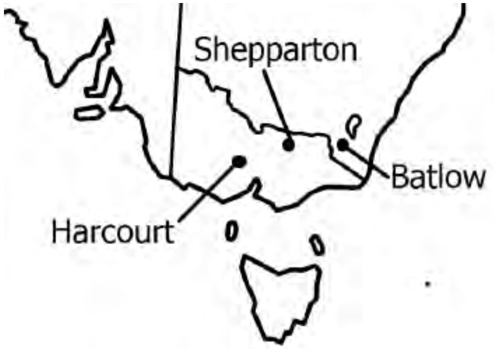


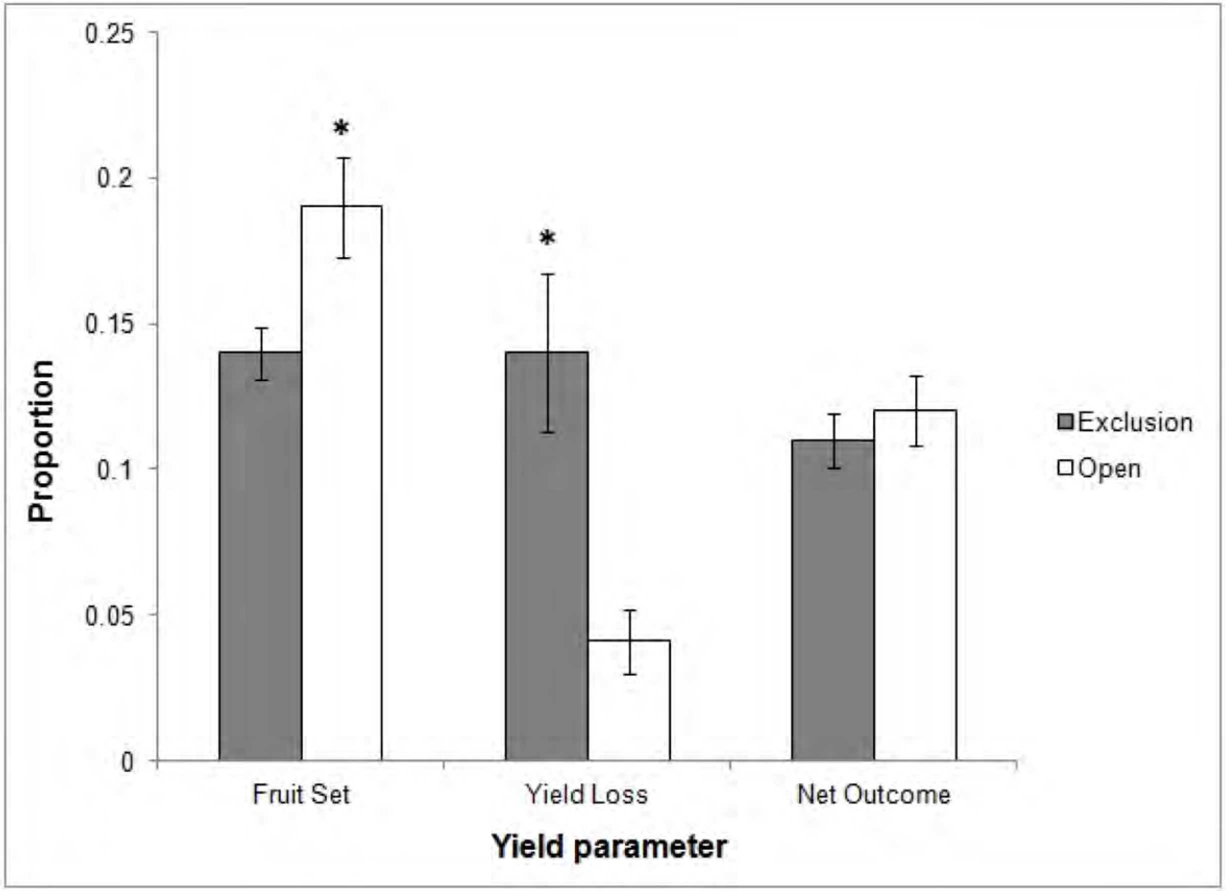




Barton & Evans (2017), Insect biodiversity meets ecosystem function: differential effects of habitat and insects on carrion decomposition. *Ecol Entomol*, **42.** 364-374. doi:10.1111/een.12395

Birds as pest control in apple orchards in Vic & NSW





Saunders ME, Luck GW (2016) Combining Costs and Benefits of Animal Activities to Assess Net Yield Outcomes in Apple Orchards. PLoS ONE 11(7): e0158618. doi:10.1371/journal.pone.0158618.

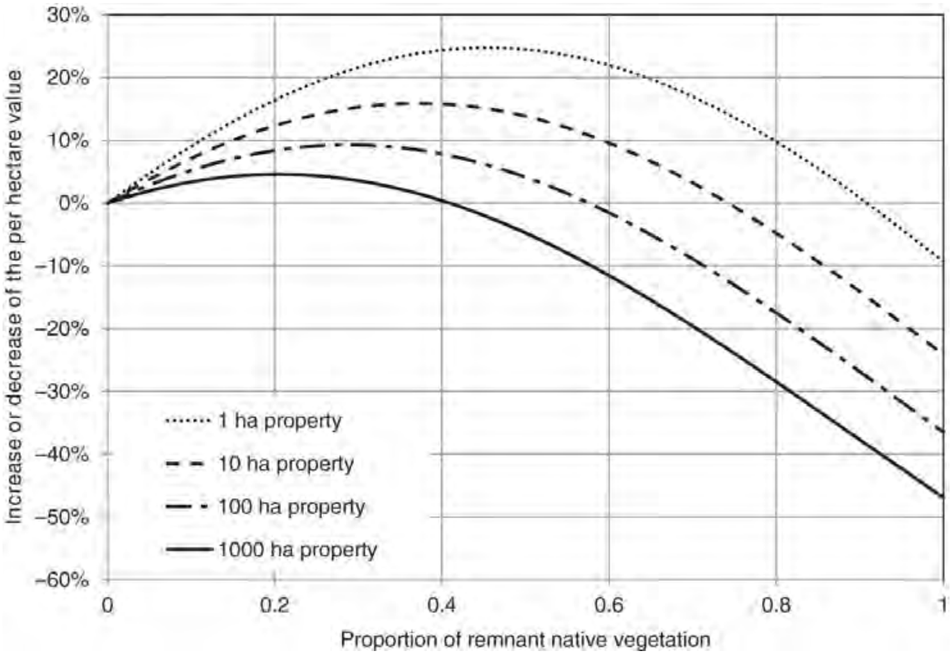
Regent parrots and the ‘mummy’ nuts

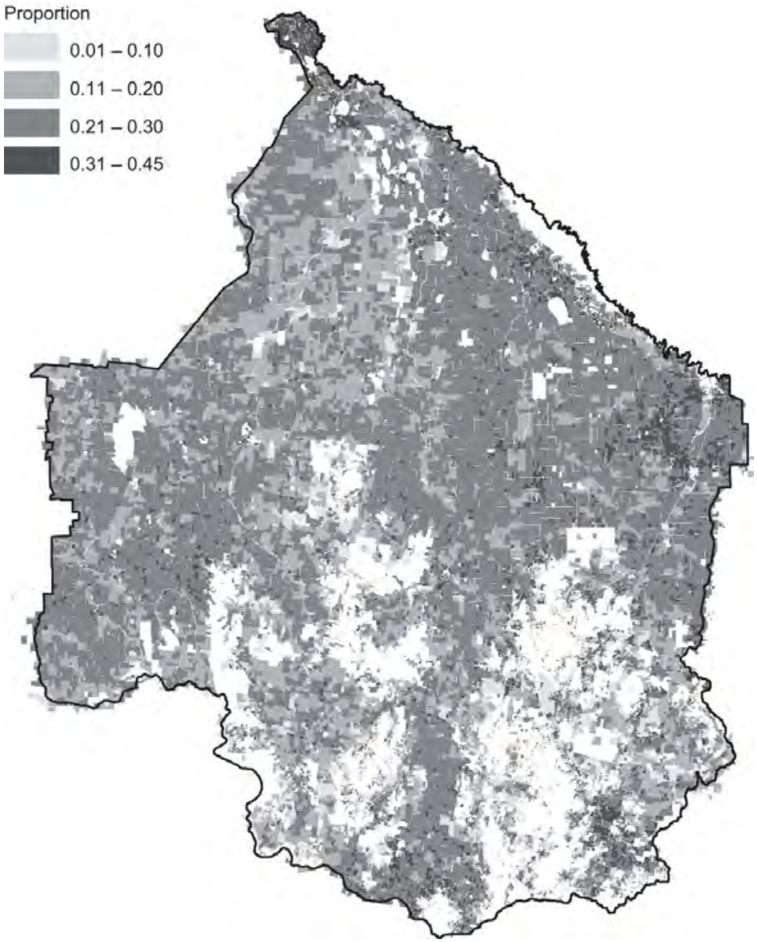
- During harvest, some almonds fail to drop.
- These “mummy” nuts act as reservoirs for fungal and insect pathogens that reduce future crop yields.
- Conventionally, growers remove mummy nuts using a mechanical tree shaker or by hand.
- Regent Parrots also remove mummy nuts.
- Economic benefit of this ecosystem service is greater than loss incurred by birds to harvest by $25-$275 / ha, resulting in a positive net return.

Marvellous micro-bats

- Bats are widespread; use a variety of habitats; high diversity of species.
- On Northern Plains, highest levels of activity in riparian vegetation and smaller blocks (< 200 ha) of remnant vegetation within farmland.
- Activity levels in roadside vegetation and scattered trees in paddocks were similar to larger blocks of forest.
- More bats using isolated trees in paddocks than cleared open farmland.
- Females of the Lesser Long-eared Bat recording feeding up to 12 km away from roost sites.
- Bats can consume up to half their body weight in insects per night; feed extensively on a range of pest species, including Rutherglen Bugs.

Increase the value of your farm





10 ha property – 37% cover (increase value by 16%)

100 ha property – 29% cover (increase value by 9%)

1000 ha property – 20% cover (increase value by 5%)

From Polyakov et al. (2014) *American J of Ag Economics*

Biodiversity benefitting agriculture

Service Provider	Facilitating practice	Ecosystem Service	Production gain	Magnitude of benefit	Strength of evidence
Native vegetation (trees and shrubs)	Shelterbelt	Wind reduction and soil protection	Crop yield gain	High in hot, dry and windy conditions Small in mild conditions	Strong
Native vegetation (trees and shrubs)	Shelterbelt, scattered trees	Temperature regulation	Increase in wool production, weight gain and lamb survival for sheep and weight gain and milk production in cattle	Moderate in extreme conditions Small to none in mild conditions	Weak
Native vegetation (trees, shrubs and grasses)	Shelterbelts, grass strips	Intercept spray-drift and nutrient run-off	Increased efficiency of use of irrigation water and agrochemicals	Moderate	Weak
Predatory insects, spiders, mites, parasitoid wasps, insectivorous birds and bats, skinks and geckos	Shelterbelts, insectariums, remnant vegetation, scattered trees	Biological control of invertebrate pests (replacing chemical treatments)	Reduced use of pesticides leading to cost saving and improved soil biology (increased productivity); reduced environmental impact; increased consumer appeal (market access)	Crops & pasture – moderate Orchards – small Vineyards – high	Weak Weak Strong

Biodiversity benefitting agriculture

Service Provider	Facilitating practice	Ecosystem Service	Production gain	Magnitude of benefit	Strength of evidence
Wetland birds (ibis, ducks, geese)	Wetland reclamation and restoration	Biological control of invertebrate pests	Reduced use of pesticides in cropping and grazing systems; increased yields.	Moderate	Weak
Granivorous birds, ants, rodents	Shelterbelts, remnant vegetation, native pastures	Seed dispersal leading to establishment of native vegetation	Assist erosion control by stabilizing the soil, shelter for livestock and crops, and water table management	Moderate	Weak
Raptors, snakes	Remnant vegetation, scattered paddock trees	Biological control of vertebrate vermin	Reduced losses of crop and pasture to vermin and rabbits; reduced use of rodenticides (cost saving and lower environmental impact)	Small	Weak
Insects, nectarivorous birds	Shelterbelts, insectariums, remnant vegetation, scattered trees	Pollination	Essential for seed set and yields of many crops and fruits	High	Moderate
Raptors	Remnant vegetation, scattered paddock trees	Carrion disposal, disease control and displacement of undesirable scavengers that take stock	Increased survival, growth and condition of livestock	High	Weak

Biodiversity benefitting agriculture

Service Provider	Facilitating practice	Ecosystem Service	Production gain	Magnitude of benefit	Strength of evidence
Birds	Shelterbelts, remnant vegetation	Removal of waste products (e.g. 'mummy nuts') and disease control	Replace human or mechanical means of removing waste products which harbour disease / pathogens (cost saving)	Low	Moderate
Dung beetles	Inoculation, shelterbelts	Nutrient absorption / decomposition and disease control	Increased soil fertility and pasture growth; increase in weight gain and livestock products	High	Strong
Soil biota (bacteria, fungi, microinvertebrates)	Low input farming, crop rotations, soil amendments, rotational grazing	Nutrient cycling, soil carbon sequestration, soil conditioning, and decomposition	Increased soil fertility and crop yields / pasture growth; increase in weight gain and livestock products	High	Weak

Biodiversity on farms: a three-sided coin?

How does biodiversity benefit agriculture?

- Ecosystem services
- Nature @ Work
- Private benefit

How can farming minimise impacts on biodiversity?

- Regenerative agriculture
- Sustainable agriculture
- Public and private benefit

How can farmers increase biodiversity on their farms?

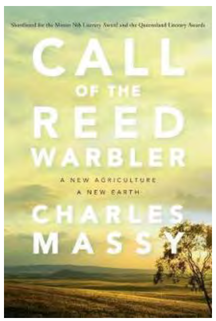
- Wildlife-friendly farming
- Habitat restoration
- Public benefit

- **Increased production / profitability**
- **Reduced environmental impact**
- **Maintain or enhance biodiversity**

Regenerative agriculture

HOLGANIX® Soil Nourishing Root Stimulating℠

Regenerative agriculture describes farming and grazing practices that focus on regenerating topsoil, allowing farmers to maintain crop yields, improve water retention and plant uptake, increase farm profitability, and support biosequestration, among other benefits.



Regenerative agriculture is an ecological approach to farming that allows landscapes to renew themselves. It promotes ethical land stewardship that *revitalises* the natural water cycle, *improves* the carbon cycle and *promotes* biodiversity in soil.

Terra Genesis International

Regenerative Agriculture is a system of farming principles and practices that increases biodiversity, enriches soils, improves watersheds, and enhances ecosystem services.

Regenerative Agriculture aims to capture carbon in soil and aboveground biomass, reversing current global trends of atmospheric accumulation.

At the same time, it offers increased yields, resilience to climate instability, and higher health and vitality for farming and ranching communities.

Regenerative agriculture … yay!

← Planet Watch, Articles & Columns | July 28, 2020 | by Willow Hallgren

Planet Watch: Regenerative agriculture as one answer to planetary crisis

Sustainability in the Field: Regenerative agriculture and biodiversity in the natural products industry

December 4, 2019
Alissa Marrapodi

RELEVANT TOPICS ▾

How much do we know about the impacts of harvesting? How do we leave the earth and soil better than we found it? How do suppliers maintain a sustainable supply chain when natural disasters and other environmental factors are greatly impacting yields?

THE CONVERSATION

COVID-19 | Arts + Culture | Business + Economy | Cities | Education | Environment + Energy | Health + Medicine | Politics + Society | Scien

Food that feeds the world and heals it too – Imagine newsletter #6

January 31, 2020 3.03am AEDT

Farmers turn back on harsh chemicals, improve biodiversity and lower costs

Landline / By Pip Courtney and Kerry Staight

Posted Sat 18 May 2019 at 6:07am, updated Sat 18 May 2019 at 7:03am

Boost Biodiversity with Regenerative Agriculture

Produce healthy food and manage pests naturally by focusing on soil health and promoting biodiversity.

By Jonathan Lundgren | *August/September 2020*

Home › Blogs › Growing Returns › These farms planted wildflowers to attract bugs to...

These farms planted wildflowers to attract bugs to control pests. And it's working.

Regenerative agriculture … boo!

Why farmers should avoid magic and opt for science

Phil Holmes and Ian McLean

16 Oct 2019, 1:30 p.m. News

Regenerative agriculture is a 'nonsense' solution to climate change, soil scientist warns

New Zealand Herald | August 14, 2020

"Hidden within the RA (and to an extent cell grazing) approach are the very things that conventional agriculture advocates - matching stocking rates to carrying capacity, retaining appropriate levels of ground cover and residual biomass in the landscape. There is nothing mysterious or new about these approaches- it's what all good land managers and grazing scientists have been advocating for decades."

THE CONVERSATION

Academic rigour, journalistic flair

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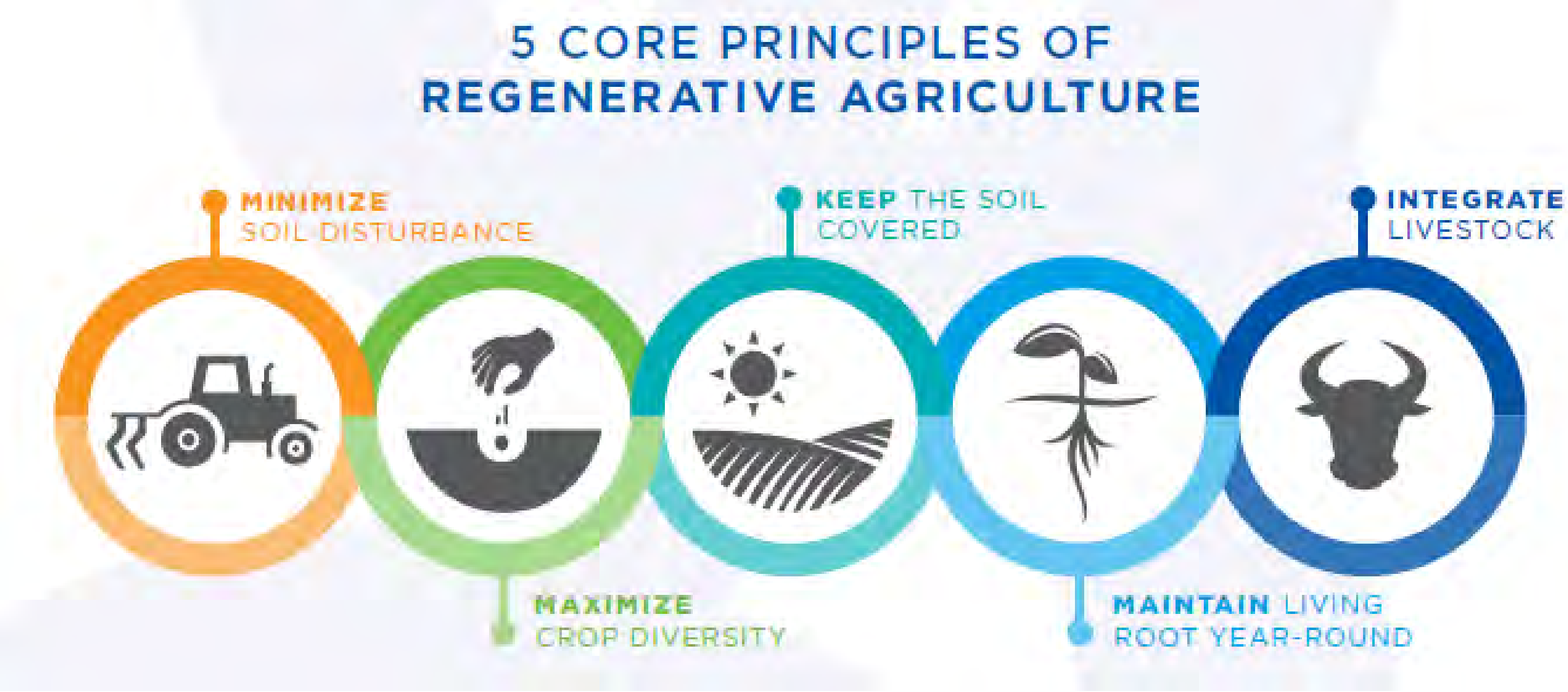
Dishing the dirt: Australia's move to store carbon in soil is a problem for tackling climate change

August 17, 2020 6.13am AEST

Plant scientists want New Zealand to fact check 'mythology' surrounding regenerative farming

Sally Rae | Otago Daily Times | June 11, 2020

So what is ‘regen ag’?



Radford's definition of regen ag

Regenerative agriculture is a set of practices. Individual farmers select and adopt various practices to include in their customised version of 'regenerative' farming, depending on their particular farming philosophy and the prevailing climatic, edaphic, geographic, economic and social conditions.

Which practices?

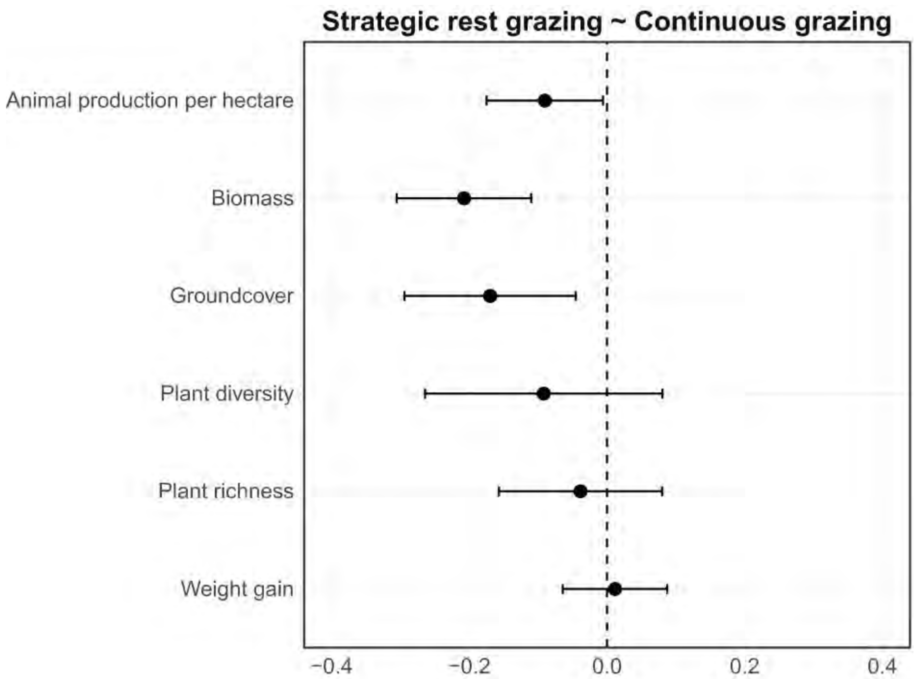
- Minimal (i.e., “low-input farming”) or no (i.e., “organic farming”) application of synthetic (inorganic) fertilisers, herbicides, pesticides and fungicides;
- Holistic grazing management (Savoury method) / timed / rotational / cell / strategic rest grazing;
- Integrated pest management;
- Incorporating wooded or perennial vegetation elements (e.g. riparian buffer strips, hedgerows, windbreaks, floral strips, biofilters and grass strips) in production areas;
- Conservation tillage (no-till or minimum till), stubble retention and maintaining ground cover;
- Organic amendments (e.g., manure, compost, biochar);
- Diverse crop rotations;
- Innovative cropping methods - cover crops, inter-cropping, poly-culture, and pasture-cropping;
- Agroforestry and silvopasture (integration of trees in pasture);

Rotational grazing

EverGraze Project (Badgery & Michalk 2017 *Animal Production Science*, **57**, 1869–1876)

- 21% higher pasture growth
- 22% higher stocking rate
- 20% higher lamb production per hectare
- whole-farm profitability lower due to higher infrastructure costs

Global meta-analysis (McDonald et al. 2019 *Journal of Applied Ecology*, **56**, 2723–2731)



Organic compost in key farming markets

Market sector	Typical application rates	Soil moisture	Weed loads	Soil structure	Yields
Market gardens	Variable – up to 160 t/ha	Significant improvements recorded	Not reported	Small improvements at high application rates	Decreases more common than increases
Viticulture	Not reported	Consistent improvements reported	Consistently suppresses weeds	Speculated but little evidence	Increase yields
Horticulture	Not reported	Consistent improvements reported	Consistently suppresses weeds	Not reported	Inconsistent: significant for some varieties and seasons
Broad-acre cropping	Commonly 10-40 t/ha up to 90 t/ha	Consistent improvements reported	Likely have little effect due to low application rates	Speculated but little evidence	Consistent increases reported
Grazing	Generally less than 10 t/ha	Insufficient evidence	Likely have little effect due to low application rates	Insufficient evidence	Increases in pasture dry matter due to fertiliser effect

Engleitner, S. (2015). *Review of past recycled organic field trials in Victoria (1995–2013).* Sustainability Victoria.

Reducing insecticide application

Conventional (apply insecticide)

Low input (apply insecticide)

Control (no insecticide)

5 sites across 4 states, across two years, and testing canola and wheat

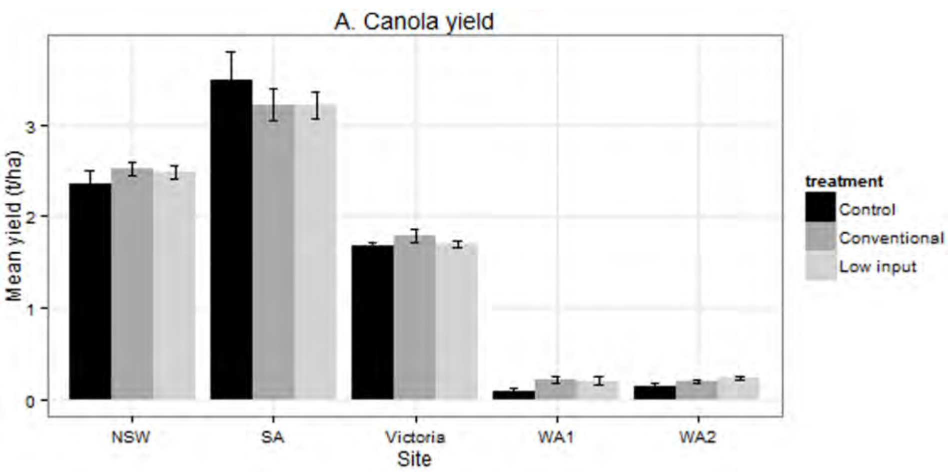
Macfadyen et al. (2014) Reducing Insecticide Use in Broad-Acre Grains Production: An Australian Study. PLoS ONE 9(2)

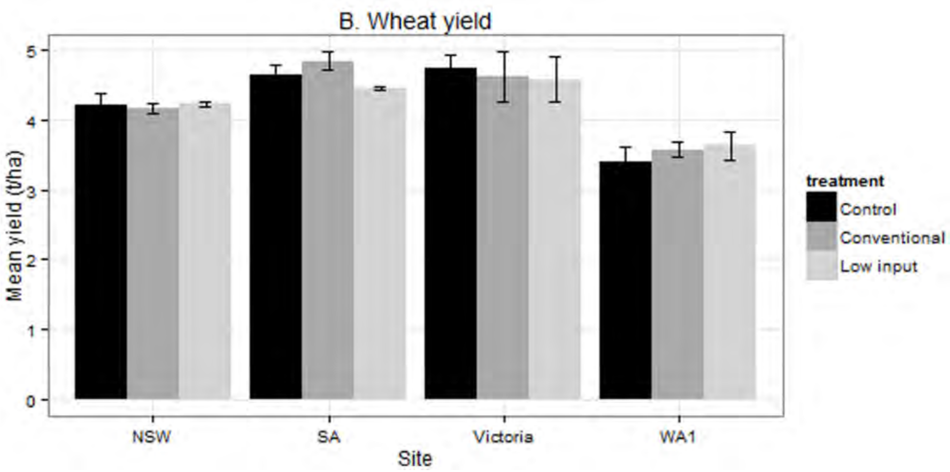
More pests but similar yields

- Insecticide use did reduce the abundance of many pest species

BUT

- Damage caused by pests not significantly higher in control and low input sites
- Yields not significantly different across treatments
- None of the insecticide inputs provided an economically justifiable yield gain.





Macfadyen et al. (2014) Reducing Insecticide Use in Broad-Acre Grains Production: An Australian Study. PLoS ONE 9(2)

Biodiversity on farms: a three-sided coin?

How does biodiversity benefit agriculture?

- Ecosystem services
- Nature @ Work
- Private benefit

How can farming minimise impacts on biodiversity?

- Regenerative agriculture
- Sustainable agriculture
- Public and private benefit

How can farmers increase biodiversity on their farms?

- Wildlife-friendly farming
- Habitat restoration
- Public benefit

- ➢ **Increased production / profitability**
- ➢ **Reduced environmental impact**
- ➢ **Maintain or enhance biodiversity**

What you can do to enhance wildlife habitat on your farm?

What do I have?

What should be here?

What's missing?

How can I increase productivity?

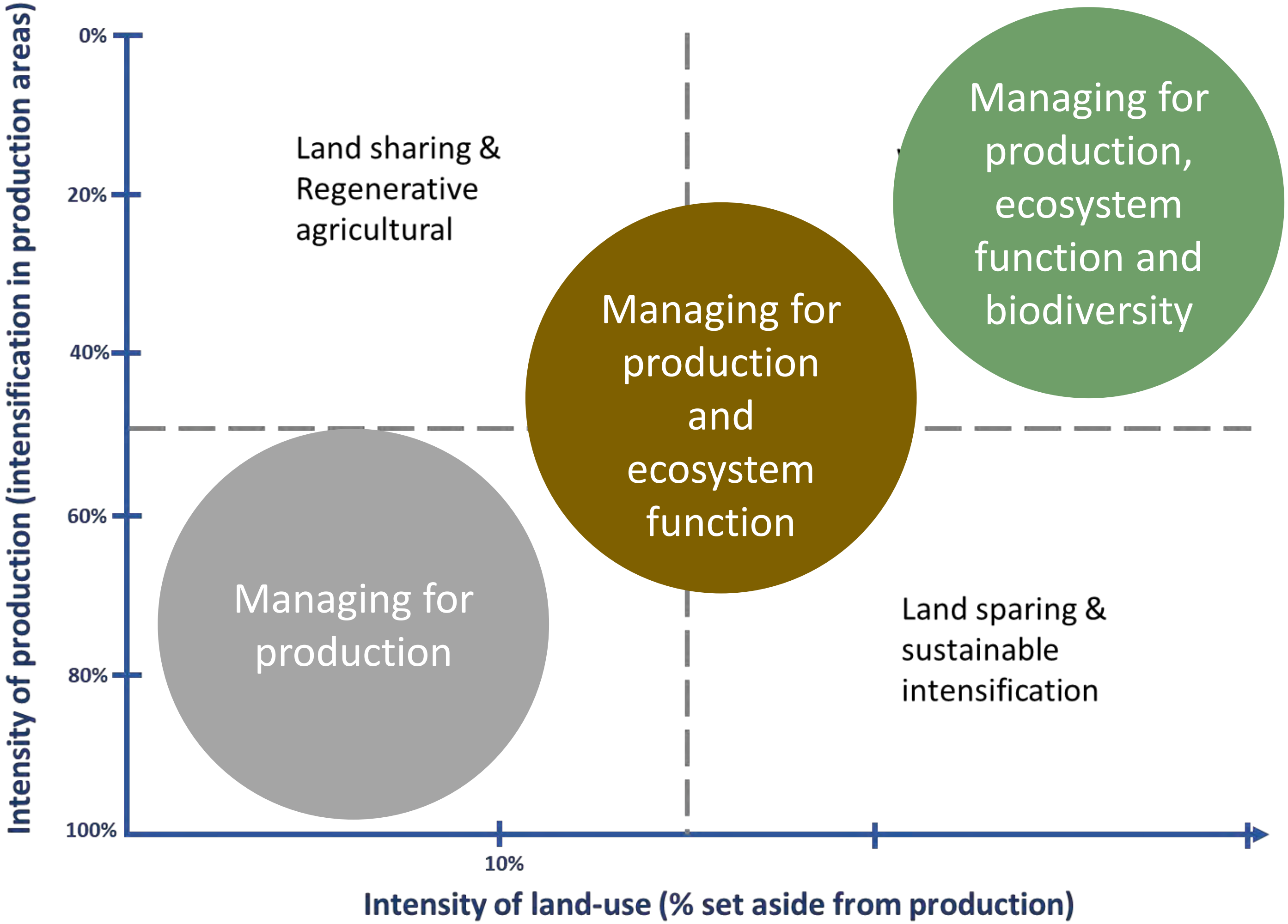
How can I support 'bottom-up' processes?

How can I increase connectivity?

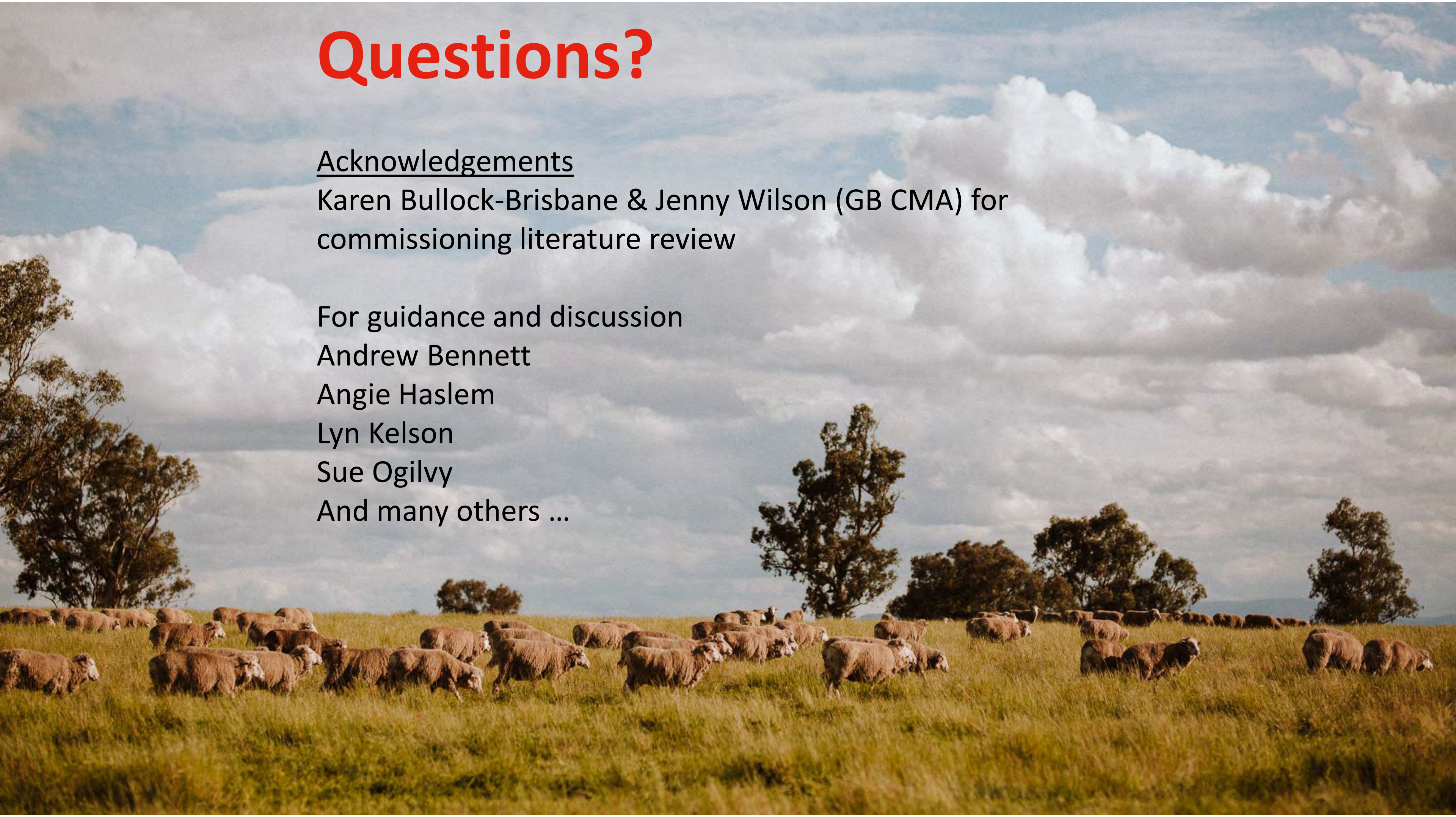
What you can do to enhance wildlife habitat on your farm?

1. Maintain all remnant vegetation
2. Protect and retain scattered paddock trees
3. Reduce inputs and improve your soil
4. Control feral predators and exotic herbivores (fence off critical areas)
5. Increase native veg through replanting – consider climate change, connectivity, pollinators, nectar, grasses
6. Leave fallen timber and coarse woody debris
7. Install nest-boxes and particular habitat features (native bee hotels, re-snagging, re-logging, re-rocking)
8. Reduce size of paddocks and increase heterogeneity

Frameworks for alternative agricultural paradigms



Thank you for listening



Questions?

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