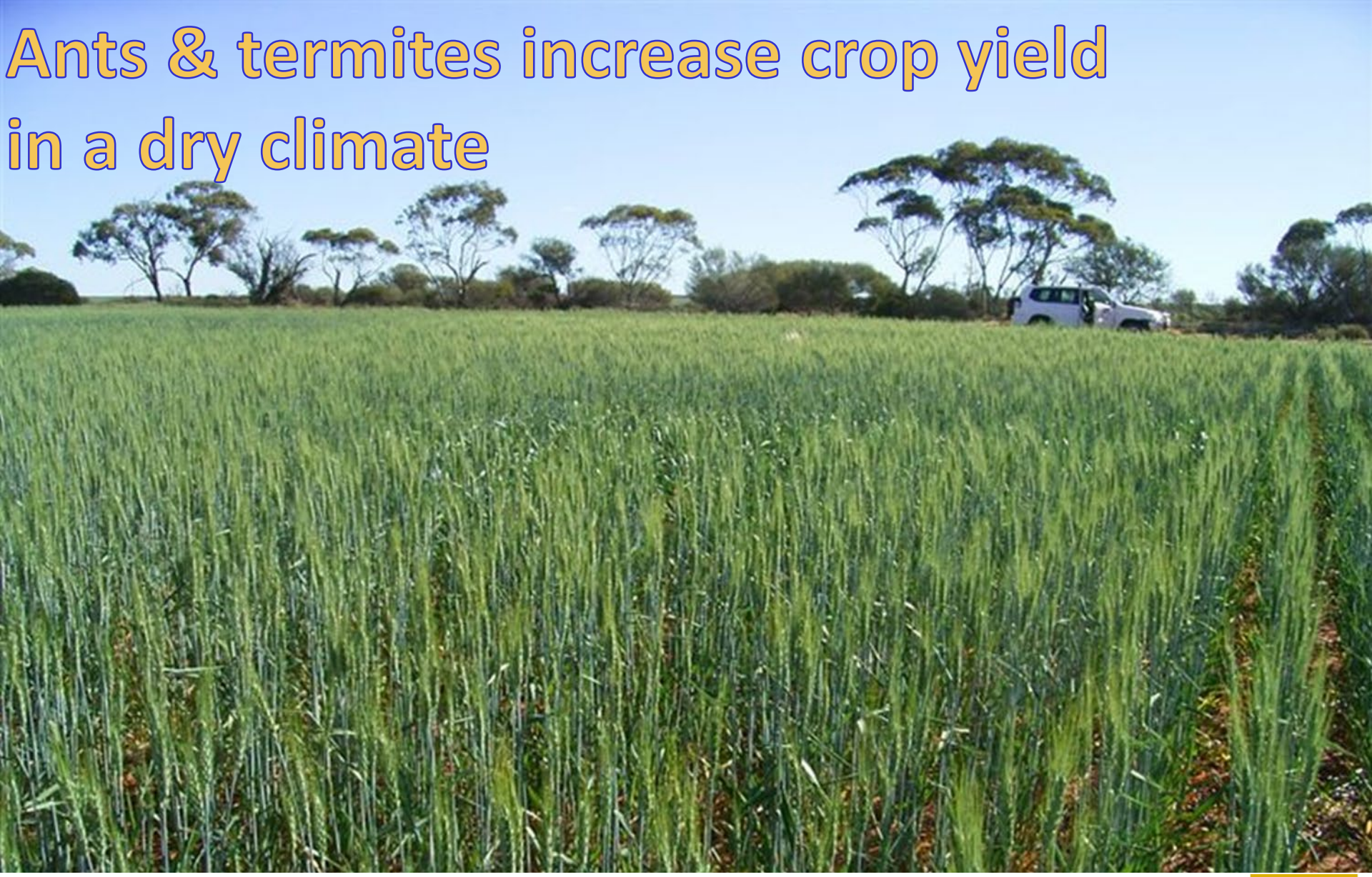
Ants & termites increase crop yield in a dry climate



Theodore Evans

University of Western Australia

Invertebrate ecosystem services

Plants and insects have very long co-evolutionary history, thus insects affecting plants also affect ecosystem services

Negative –

- herbivory = pests of plants

Positive –

- Pollination
- Predation & parasitism of herbivores: ‘natural enemies’
- Dung burial
- Nutrient cycling in soil

Bornemissza et al 1970 *Pedobiologia* 10, 1-7; Klein et al 2007 *PRSB* 274, 303-313; Bianchi 2006 *PRSB* 273, 1715–1727; Losey & Vaughan 2006 *Bioscience* 56, 311-323

Invert ecosystem services in agriculture

Increase sustainability by reducing dependence on human inputs

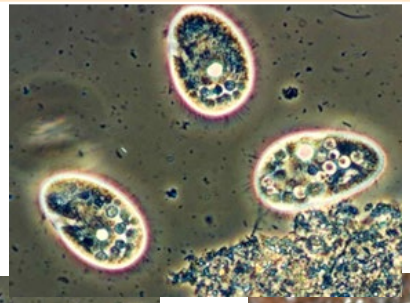
Factors investigated:

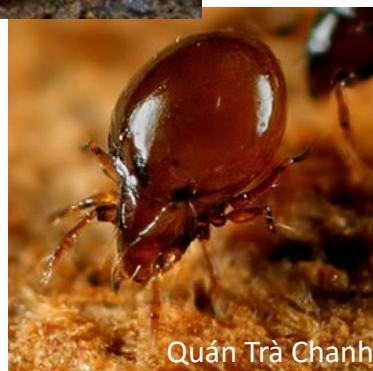
- Pollination, esp. bees, hoverflies
- Control of weeds & pests, esp. insects
- Control of disease, esp. fungi & nematodes
- Soil nutrition, esp. earthworms, dung beetles
- Decomposition & nutrient cycling

Drinkwater et al 1998 *Nature* 396, 262-265; Rasmussen *et al* 1998 *Science* 282, 893-896; Tscharntke 2005 *Ecol Lett 8*, 857–874; Boody et al 2005 *BioScience 55*, 27-38; Pimental et al 2005 *BioScience* 55, 573-582; Vince 2010 *Science* 327, 800.

Decomposition and nutrient cycling in soil

Microflora	Microfauna	Mesofauna
Bacteria & fungi	Protozoa & nematodes	Mites, springtails & potworms
solubilise, oxidise, reduce, mineralise, fix **N, P, S, Fe…**	eat bacteria, fungi	eat bacteria, fungi, micofauna, each other
degrade **CHO**, cellulose, lignin to 2°compounds	Increase mineralisation	Increase mineralisation; Break up plant matter





Soil macrofauna

Earthworms, termites, ants & millipedes

Physical processes:

- break up plant matter
- mix of soil
- tunnelling = soil macropores
  gas exchange, water infiltration
- Concentration of nutrients
  esp. in nests

Chemical processes:

- mineralisation of nutrients
- gut microflora, fix/reduce N, P, S?
  esp. in termites (earthworms?)

Earthworms

- Most studied soil macrofauna
- Most research conducted in agricultural systems, cooler and wetter climates, especially Europe and North America
- Positive effects on soil structure, decomposition, nutrients, microfauna, microflora
- Natural systems?
- Hotter and drier climates?

Lee, 1985. *Earthworms: their ecology and relationships with soils and land use*, Academic, NY; Edwards & Bohlen, 1996. *Biology and Ecology of Earthworms 3rd edn*, Chapman & Hall, UK.

Ants & termites

- Less well studied
- Most research conducted in natural systems, esp. Africa and South America
- Ants and termites replace earthworms in hotter and drier climates
- Positive effects on soil structure, decomposition & nutrients
- Can ants and termites have positive effects in agricultural systems in hotter and drier climates?

Lal 1988 *Agric Ecosyst Environ* 24, 101-116; Lobry de Bruyn & Conacher 1990 *Aust J Soil Res* **28**, 55-93; Lavelle et al 1997 *Eur J Soil Biol* **33**, 159-193; Mora et al 2003 *Biol Fertil Soils* **37**, 245-249; Bradford et al 2002 *Science* **298**, 615-618

Dryland cropping in Australia

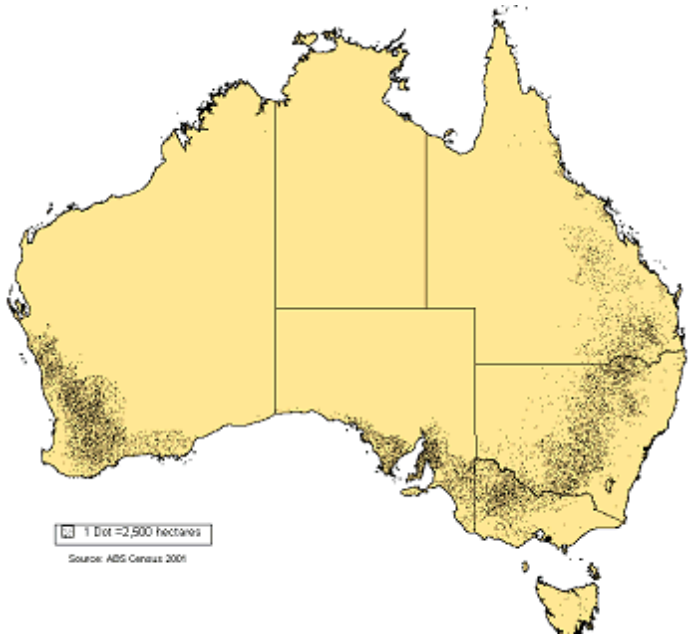
- ca. 25 plant species
- dominated by wheat, barley, canola

- often in hotter and drier areas,
- esp. relative to earthworm physiological requirements

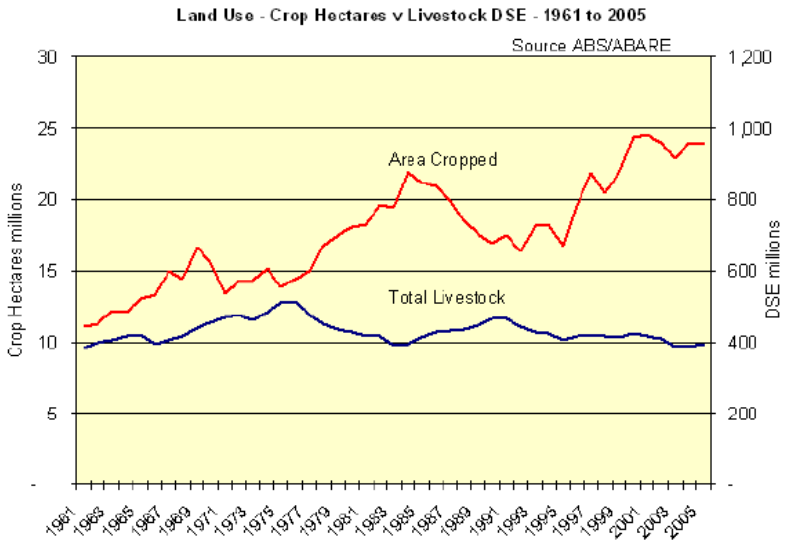
- Important industry:
- 83% cereals, 10% legumes,
- 7% oilseed

- ~ 60% production exported.

- Increasing in area



www.cropscience.org.au



ABS / ABARE

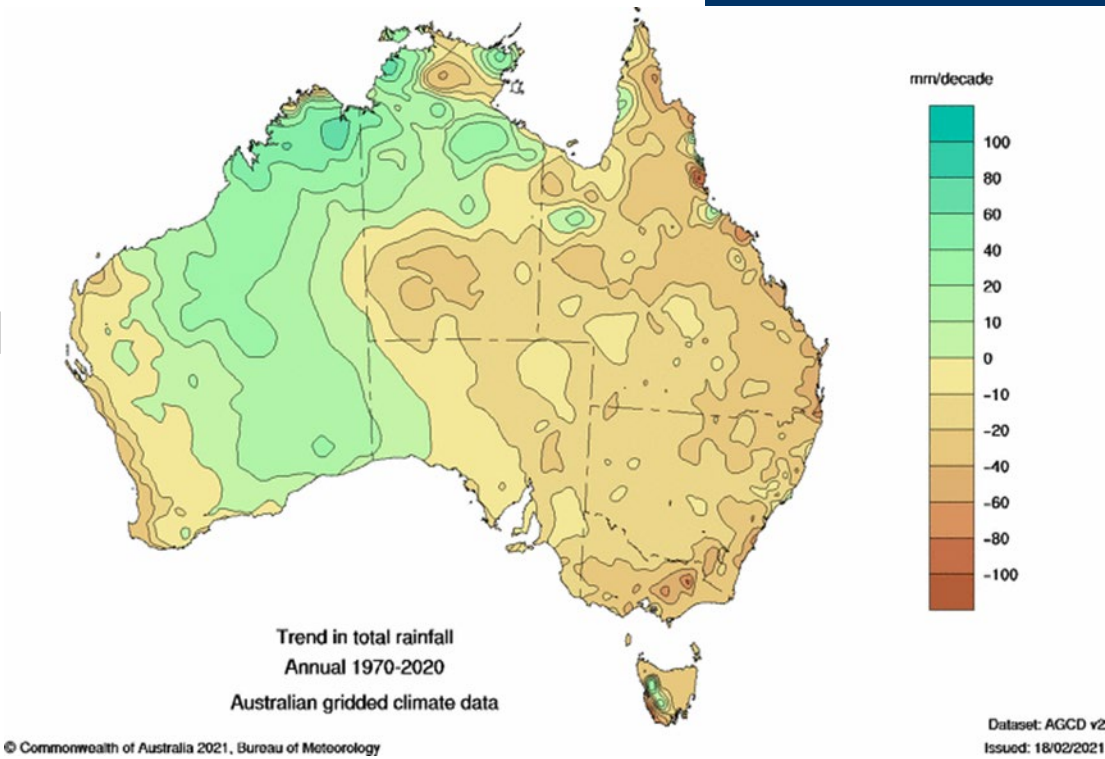
Emerging issue in dryland cropping

Climate change:

Especially decrease in rainfall

Rainfall predicted to decrease 30 – 180mm in subtropical and warm temperate latitudes, resulting in a decrease of up to 20% soil moisture

In Australia, dryland cropping in 300 – 400 mm zone vulnerable under CC models



Solomon 2007 *Working Group I, 4th Assessment Report IPCC*; Seager et al 2007 *Science* 316, 1181-1184 ; Cassman et al 2003 *Annu Rev Environ Resour* 28, 315–58

Experiment – invert ecosystem services

Opportunity emerged at Binnu, near Northampton

Grower and ag scientists essential

Rohan and Carol Ford, owners of Nookenderi Station

Trialling many conservation ag methods

Paul Blackwell & Caroline Peek, WA Dept Ag & Food

Field site

Pilot experiment in the north of the Western Australian wheat belt

- near physiological limit for wheat
- ca. 300 mm pa rainfall; vulnerable to climate change
- Maybe predictive for southern areas?

Neighbour's farm – traditional tillage

Remnant native vegetation – source of inverts

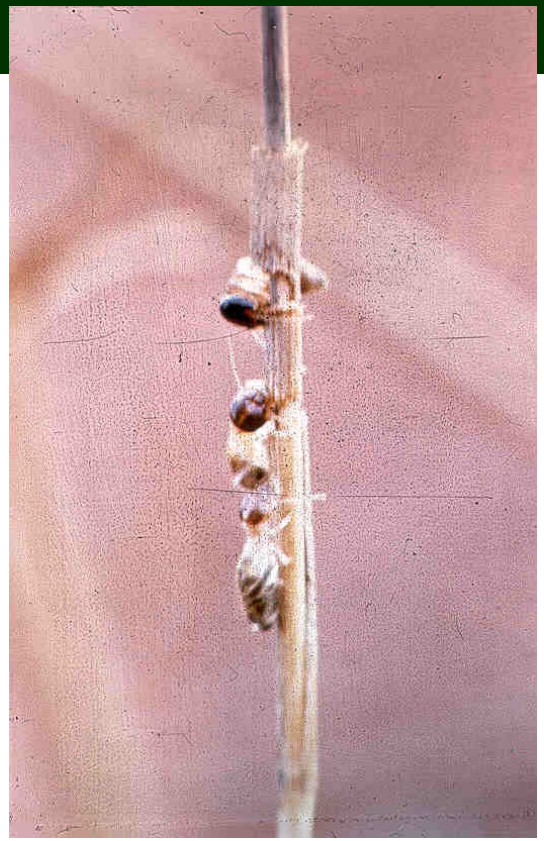
Ford's farm – low tillage & controlled traffic

Experiment plots

Conservation tillage

Essential for this experiment

- When tillage is minimised, soil biodiversity increases, esp. macrofauna
- When stubble is retained, food source provided – stubble disappears!
- Problem? Benefit?



Amitermes, *Drepanotermes* (Termitinae)
Tumulitermes (Nasutitermitinae)
Grass harvesting termites

Experimental design

Two treatments with two levels each in a split plot design.

Tillage:
present and absent

Insecticide:
present and absent

Tillage to 10 cm depth;

equivalent to weed control

- Insecticide synthetic pyrethroid bifenthrin, neurotoxin
- trade name ‘Biflex’
- Repellent & toxic

- Applied as for domestic
- termite barrier treatment, therefore much water

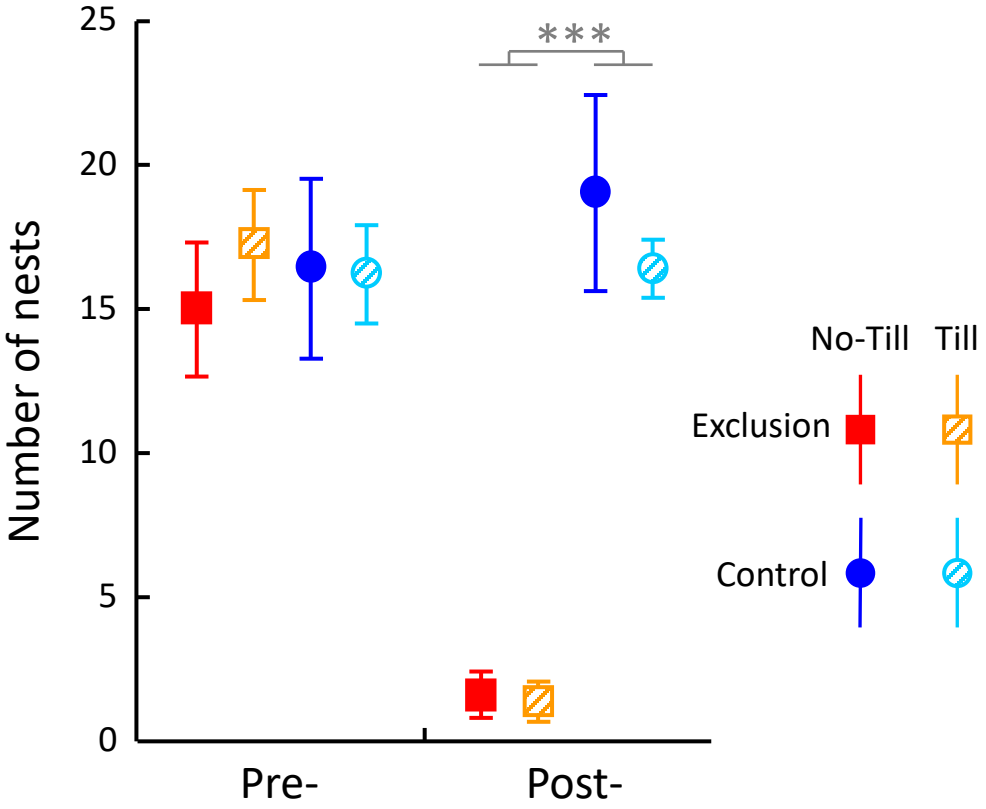
- Water controls needed

- Persists for 3 years *(maybe – very exposed in Paddock)*

Efficacy of insecticide – ants

Counting active ant nests in plots

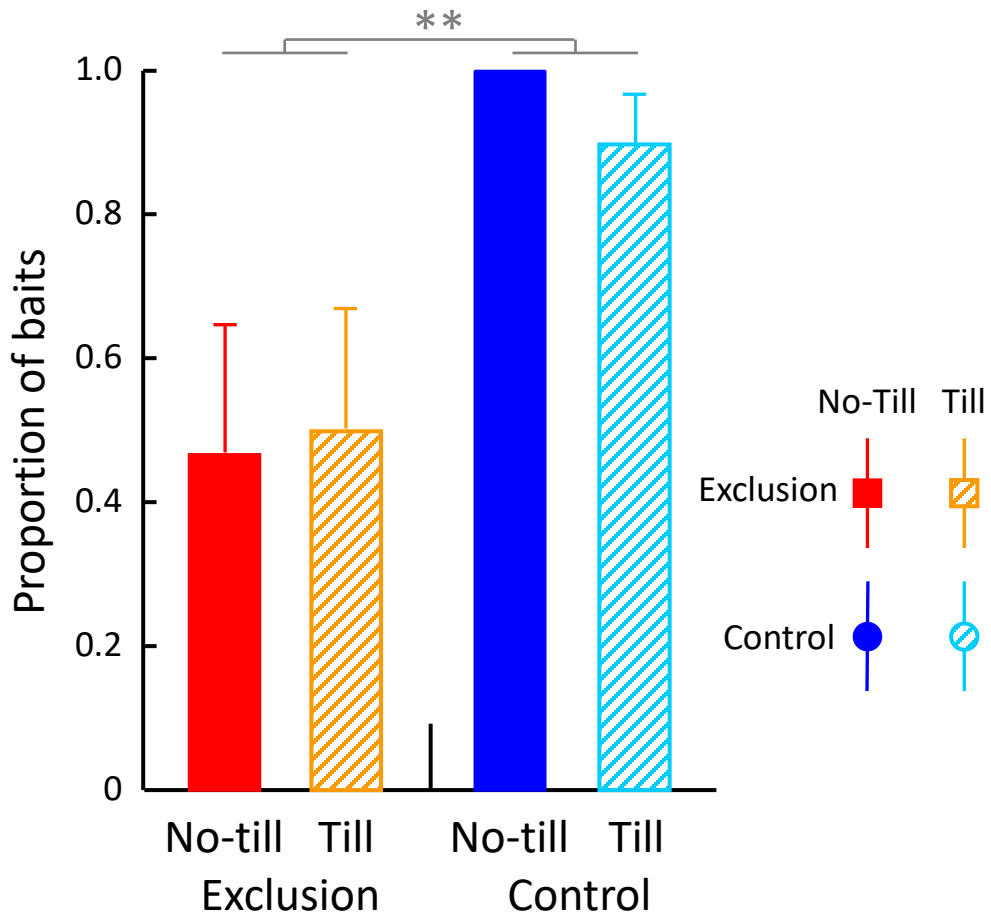
Seed eating ant nests identified by seed debris



Evans et al 2011. *Nature Communications* **2**, 1257

Efficacy of insecticide – termites

Baiting for termites in plots
6 baits with wood, toilet paper and straw in each plot



Evans et al 2011. *Nature Communications* **2**, 1257

Timing

If insecticide persists for 3 years

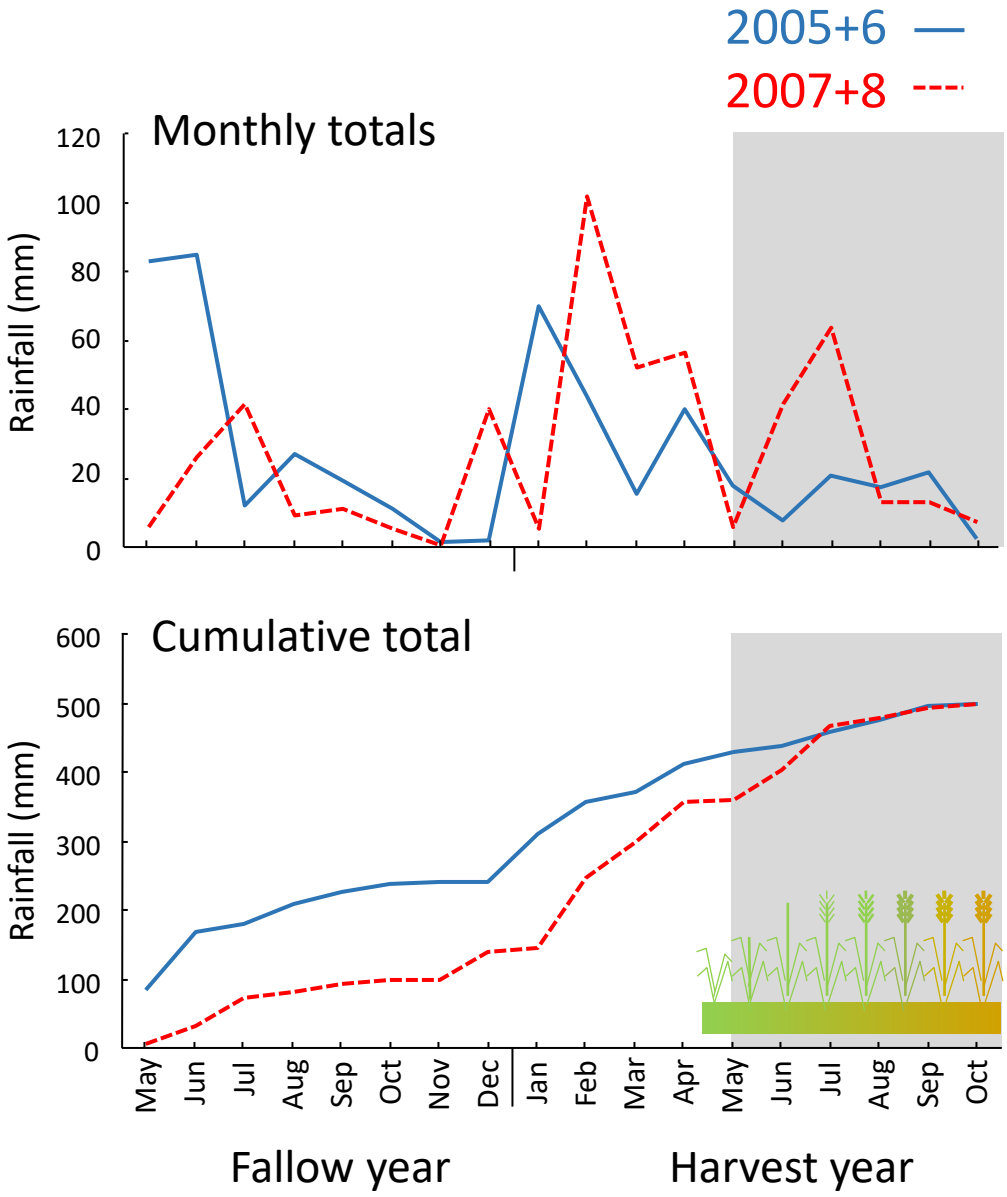
2 crops possible

2006 2007 2008

Set up

fallow

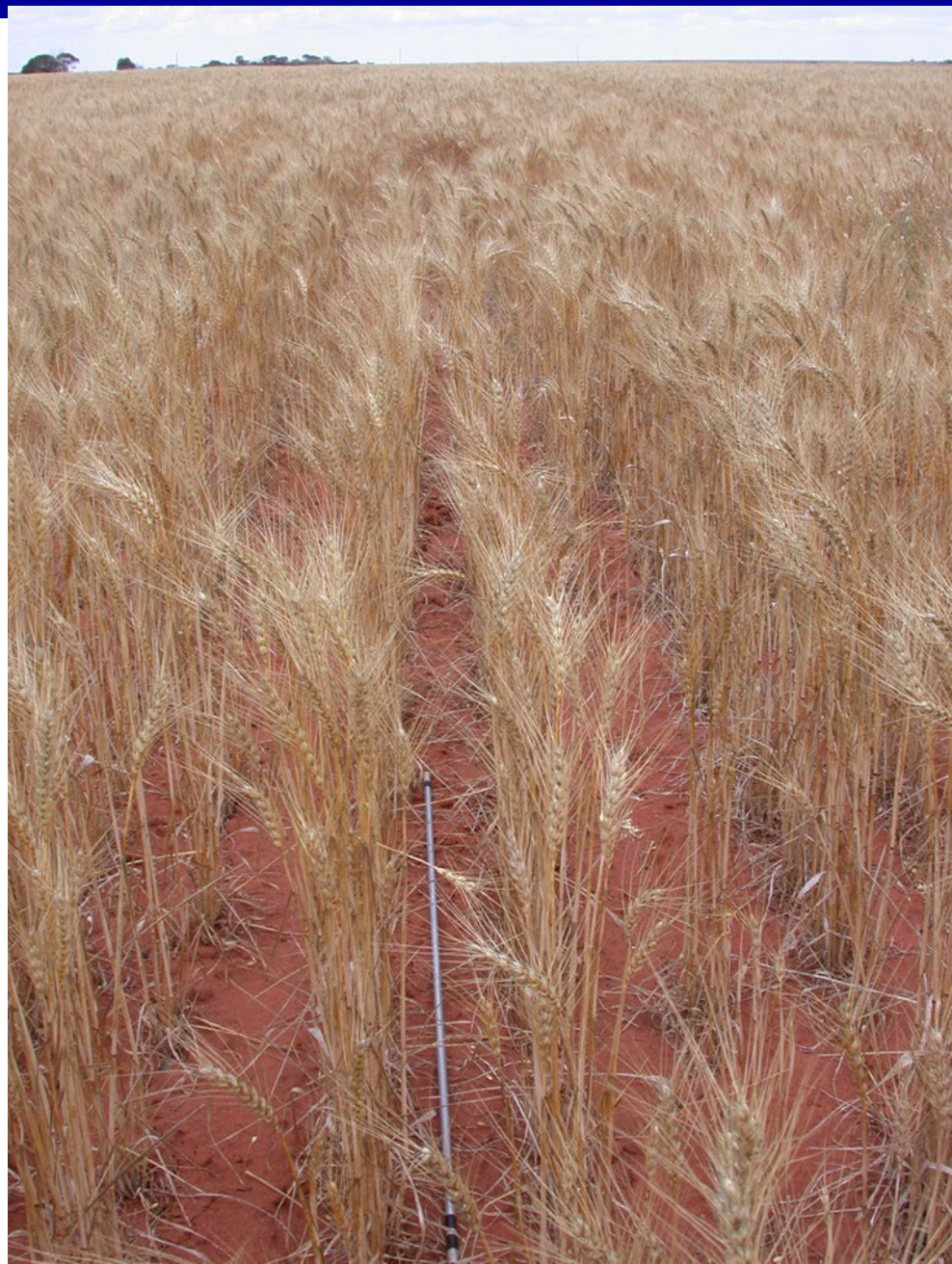
Water accumulation



Evans et al 2011. *Nature Communications* **2**, 1257

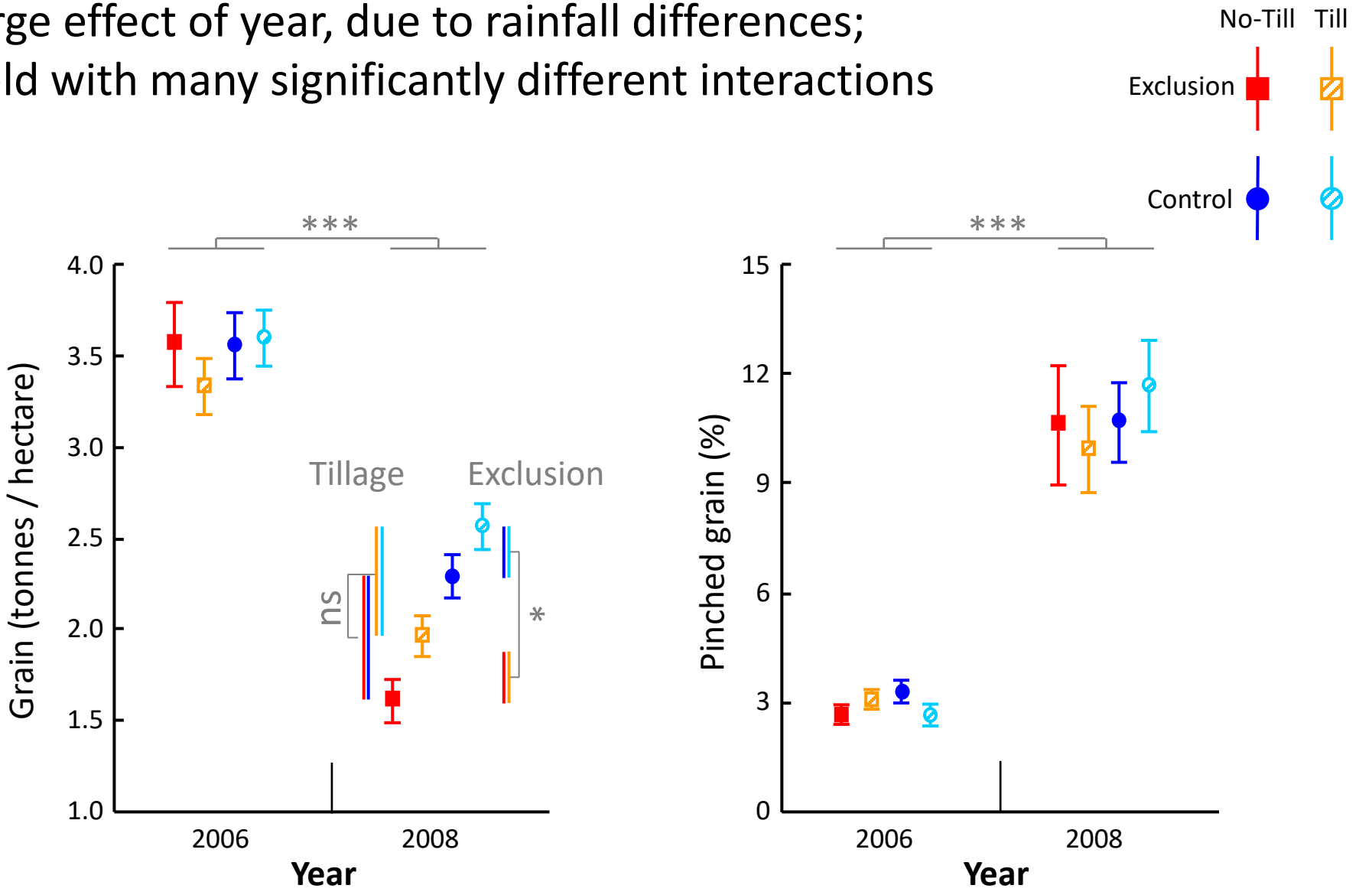
Results

Wheat sampled at harvest
10 samples of 1 m rows
haphazardly placed



Total yield, pinched grain

Large effect of year, due to rainfall differences;
yield with many significantly different interactions



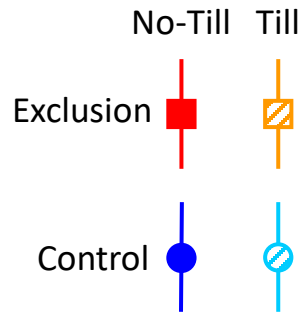
Evans et al 2011. *Nature Communications* **2**, 1257

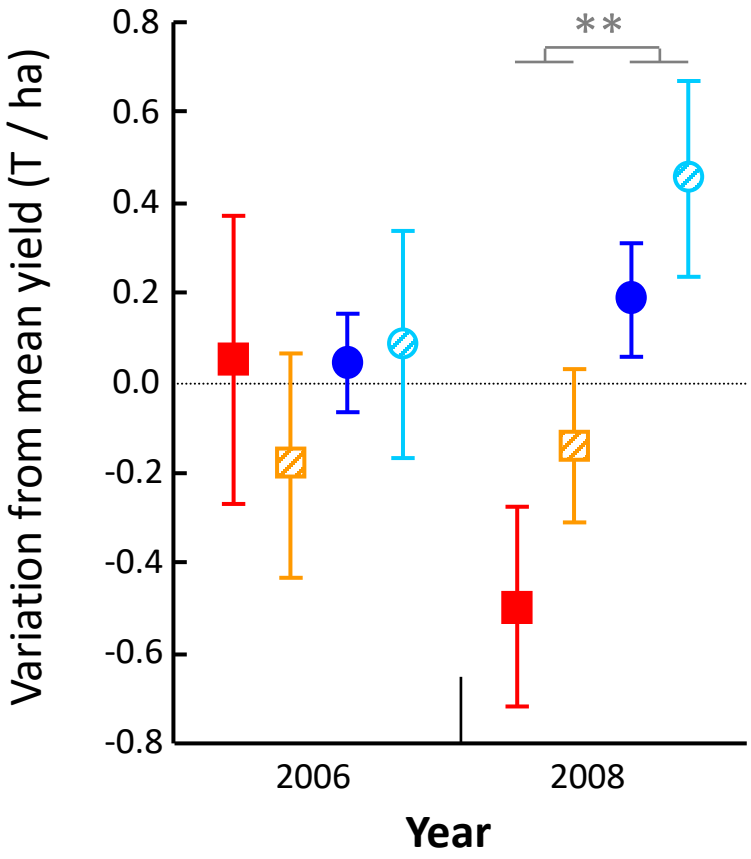
Relative yield

Removes effect of year, focuses on treatment differences

Exclusion $F_{1,16} = 10.620$, $p = 0.005$

Tillage $F_{1,16} = 2.632$, $p = 0.124$





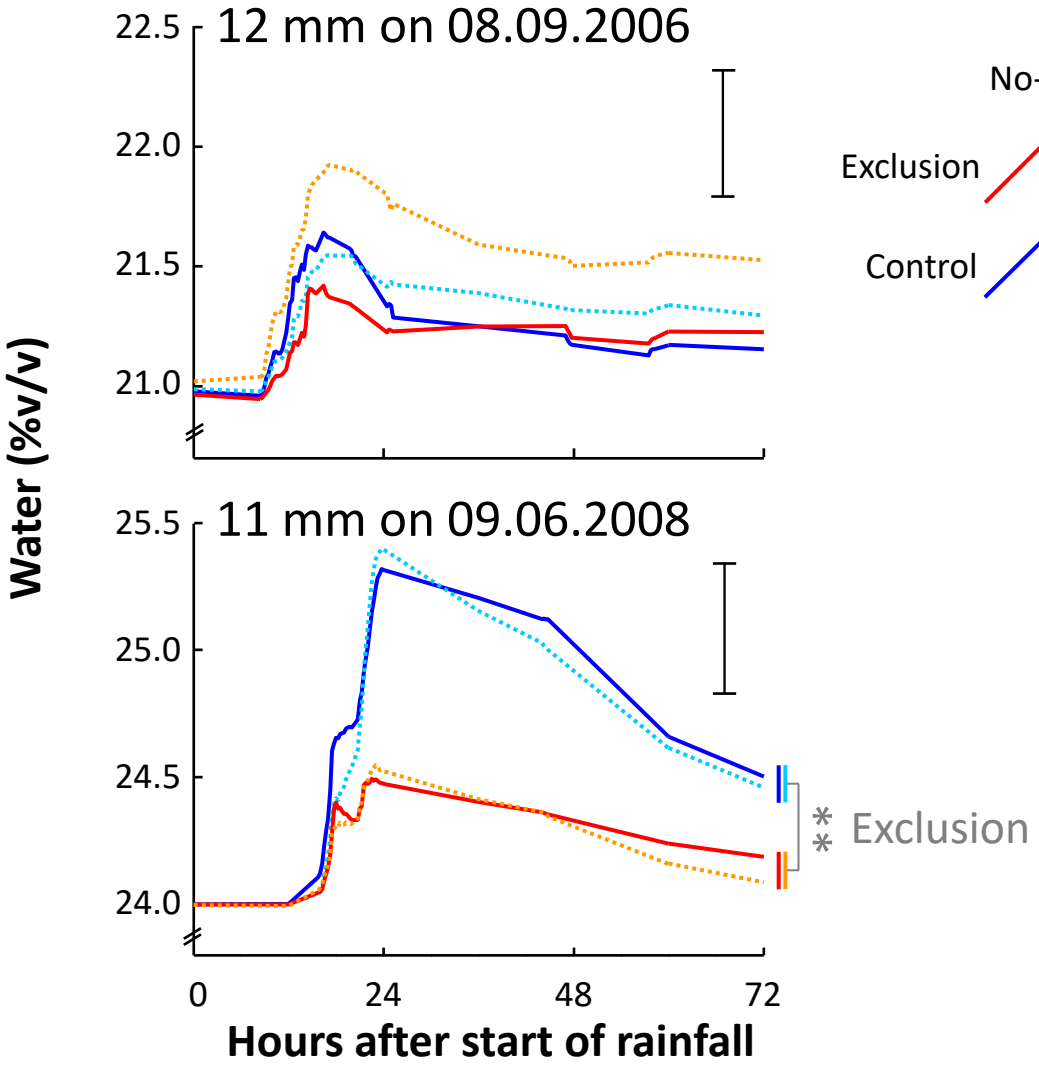
36% increase

Polyzosteria, Blattidae

Evans et al 2011. *Nature Communications* **2**, 1257

Rainfall & soil water

Two nearly identical rainfall events
Mean water (%v/v) & LSD at 50 cm depth

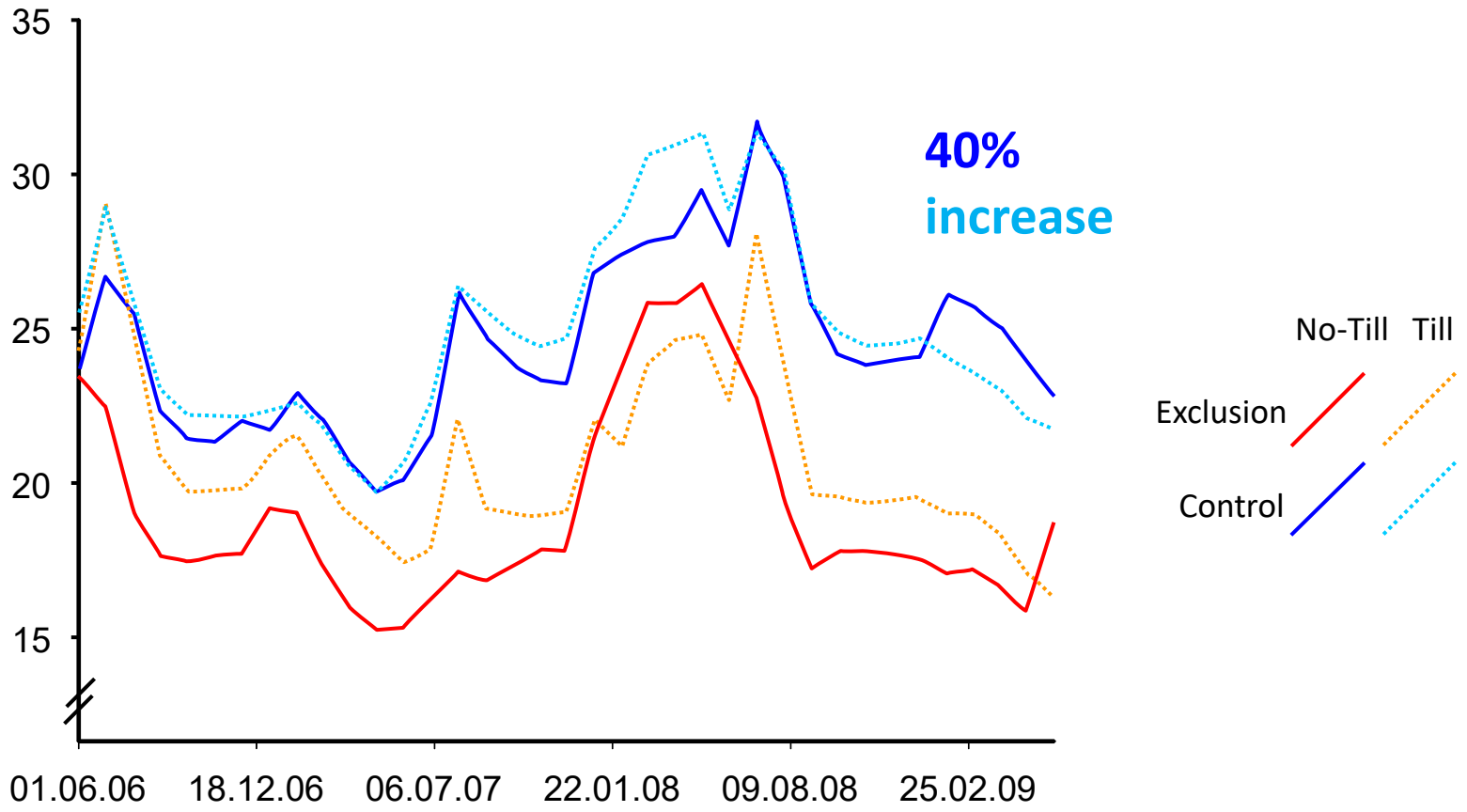


Long term soil water

Rainfall over 3 years

Mean water (%v/v) at 50 cm depth

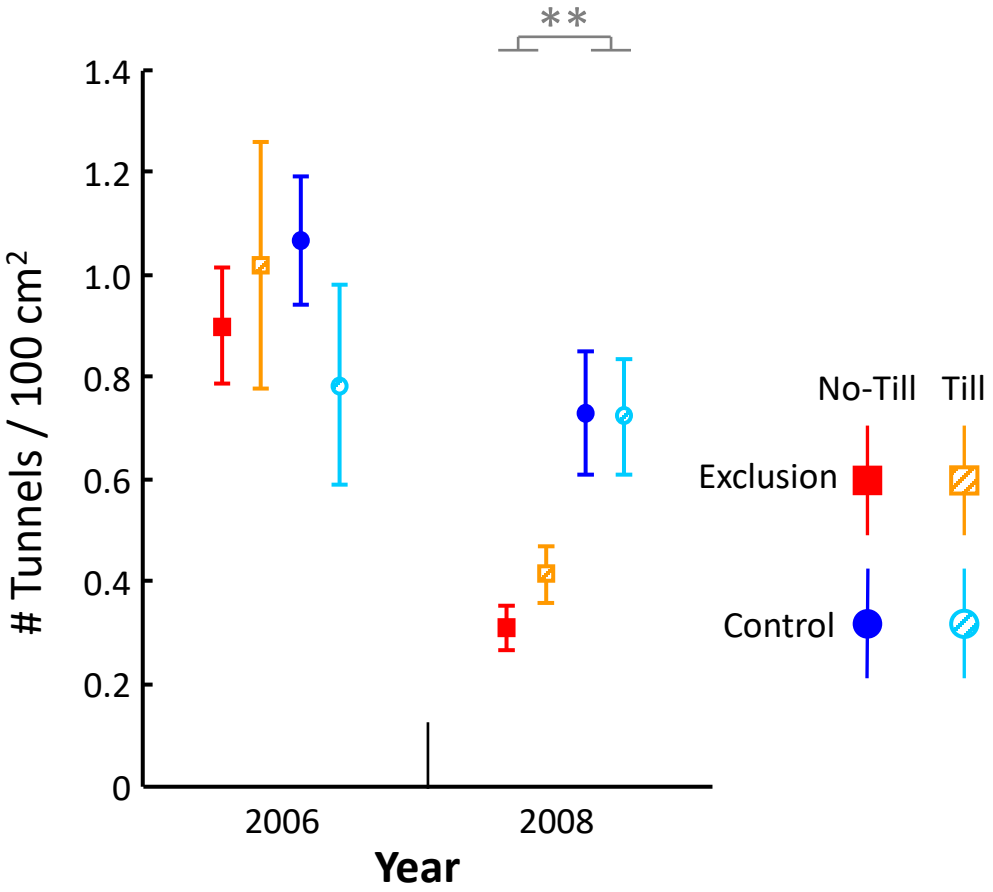
Increasing difference between exclusion differences over time



Insect tunnels = water pathways

Ants & termites

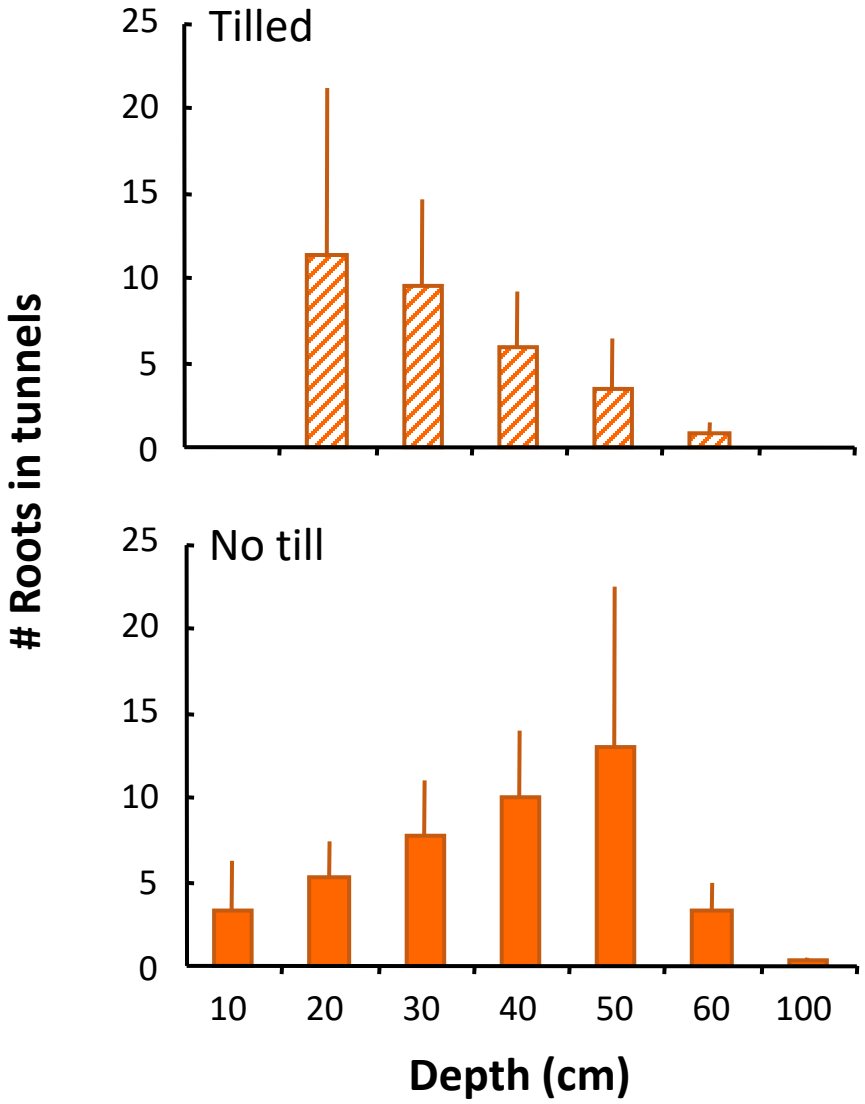
Significant decline in exclusion treatment



Evans et al 2011. *Nature Communications* **2**, 1257

Roots & insect tunnels

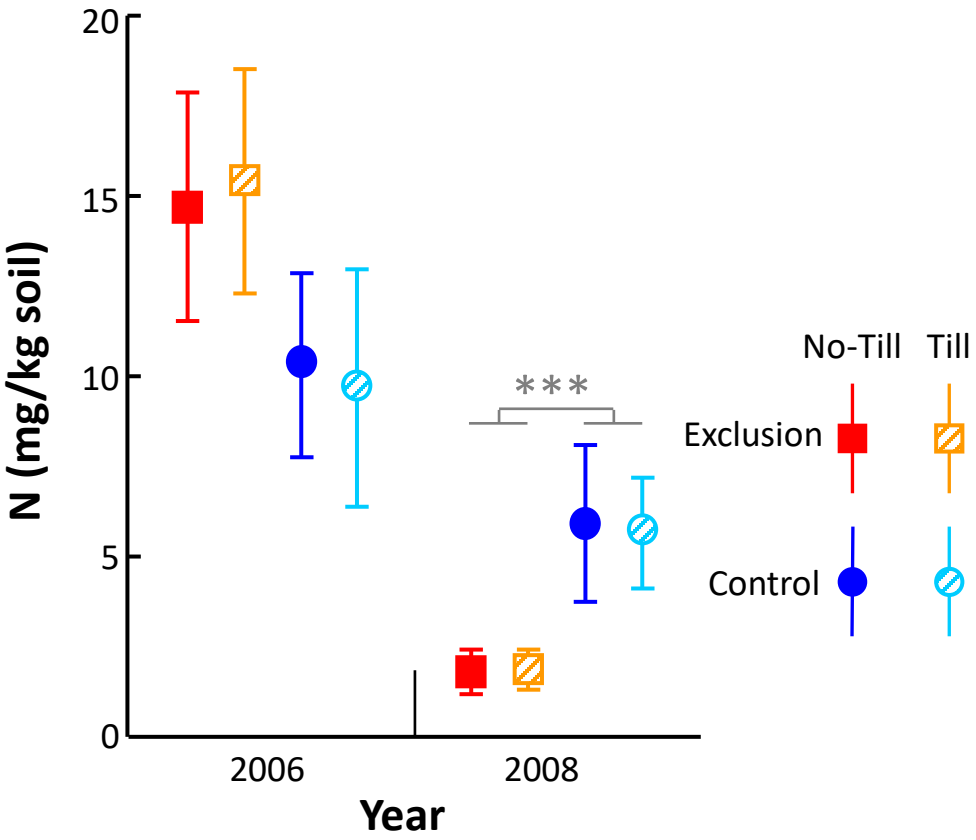
Appear to be clumped at surface in tilled plots



Soil nutrients – total mineral N

- Affect of year
- ca. 70% decrease in exclusion treatment cf. controls

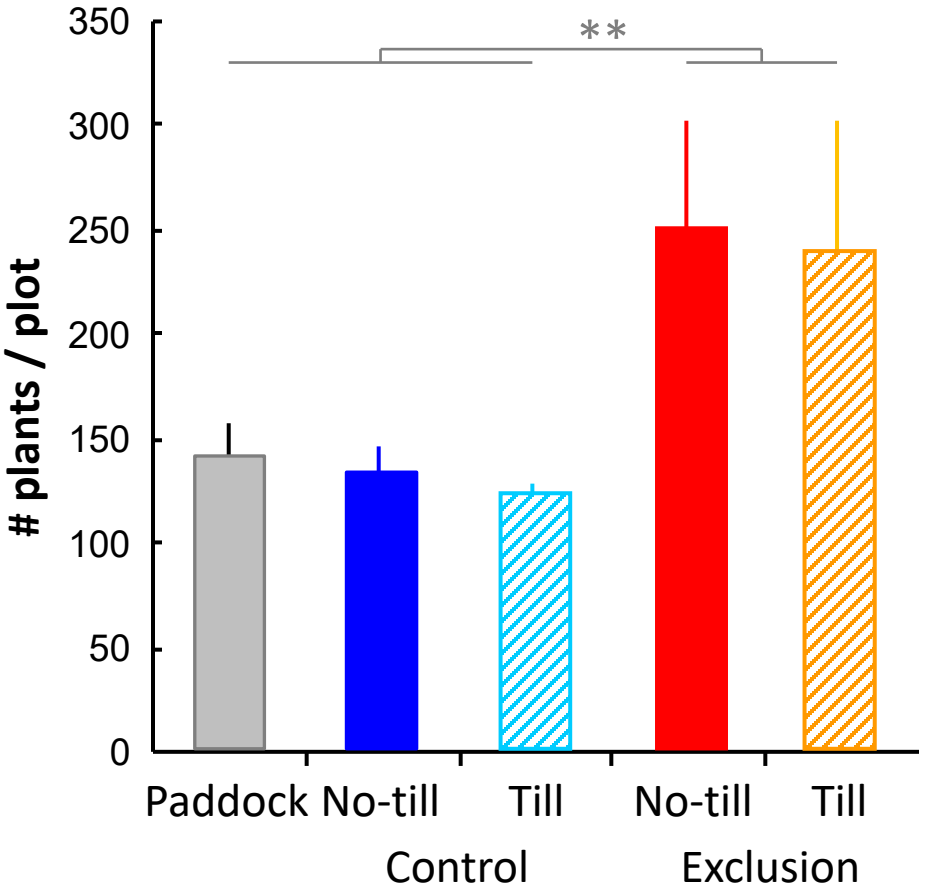
Likely due to termites with N-fixing gut microbes with *Nif* H gene



Evans et al 2011. *Nature Communications* **2**, 1257

Weed seed predation

- Single incursion of rolly-polly, *Salsola australis* (Chenopodiaceae)
- December 2006, killed with herbicide in February 2007 – fallow year
- No differences in water or soil nutrients at that time



Evans & Gleeson (2016) *Journal Applied Ecology* 53, 1177-1185

Acknowledgements

Nookenderi Station

Rohan and Carol Ford

CSIRO

Aaron Barrett, Austin Brandis, Cassidy Fitzclarence, Patrick Gleeson, Judith Lanka, & Wendy Whitby

WA DPIRD

Paul Blackwell & Caroline Peek

Thanks!

theo.evans@uwa.edu.au







Coming soon, a roller for WA wheatbelt