Reduced tillage in organic farming systems in Europe: lessons learnt from the TILMAN-ORG project

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Background

- 40% of soils in Europe are low in organic carbon
- Increased carbon stocks in top soil in organic farming (Gattinger et al., PNAS, 2012)
- Conservation agriculture to restore and ameliorate essential soil functions (crop production, biodiversity, climate mitigation)
- Conservation tillage: No till and Reduced tillage (shallow inversion, non inversion techniques, e.g. chisel)
- No till:
  - well developed in conventional systems, dependent on herbicides and mineral fertilizers
  - circa 6% lower yield than plough systems (Pittellkow et al., Nature, 13809)
  - increases carbon stocks, at least in top soil.
- Is reduced tillage a viable alternative in organic farming systems? Focus yield and soil quality

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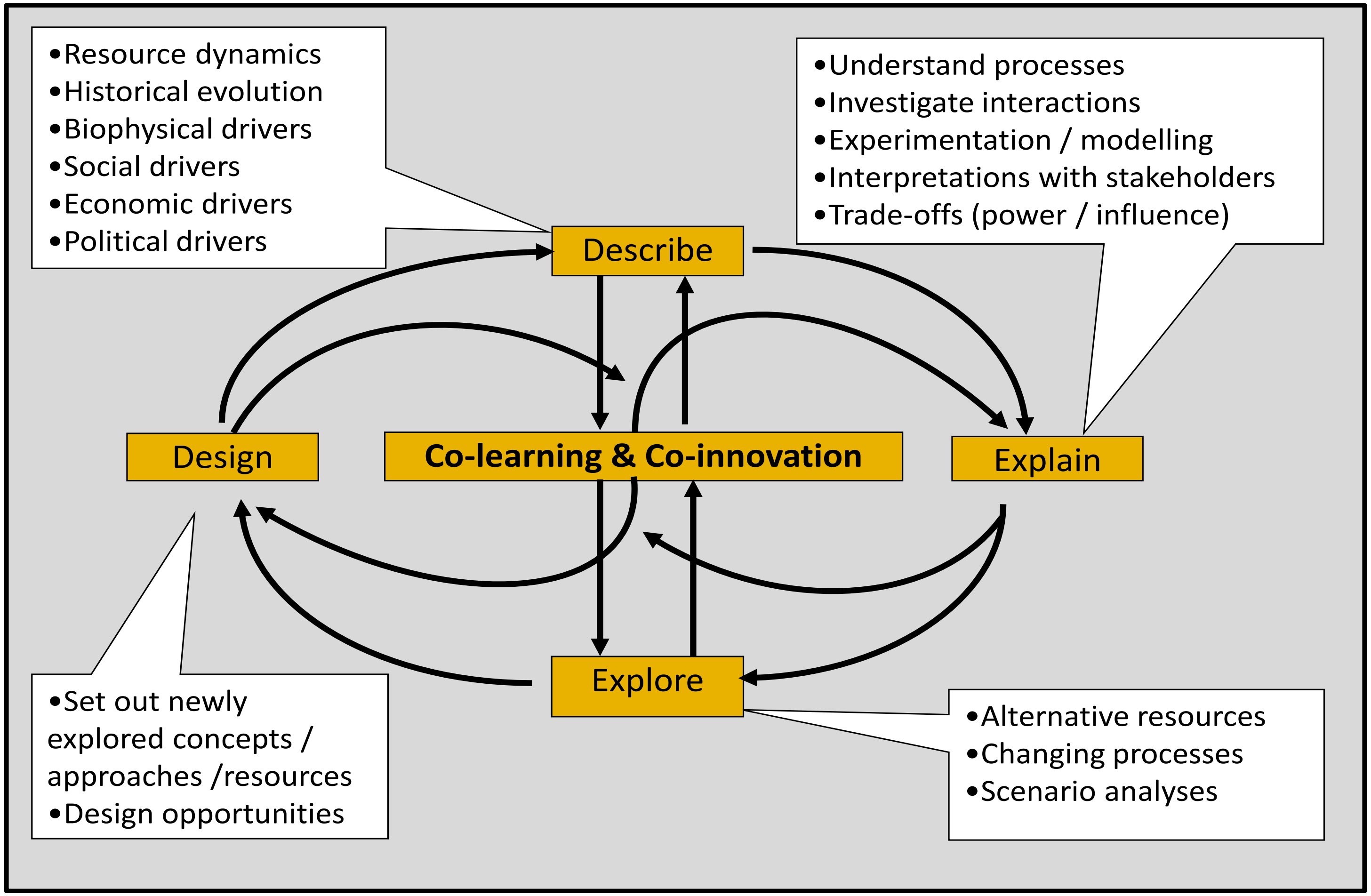
Conceptual framework TILMAN-ORG



Modified after Giller et al., 2008. *Ecology and Society* **13**(2): 34. [online]
URL: http://www.ecologyandsociety.org/vol13/iss2/art34/

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Brussard, WU

Machines for reduced tillage: examples

Chisel with wide overlapping sweeps (shallow), and narrow tines for loosening

Skim plough for removal of grass-clover and stubble cleaning

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Seed bed preparation

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TILMAN-ORG: Reduced tillage and green manures for sustainable organic cropping systems

"The TILMAN-ORG project's overall goals are to design improved organic cropping systems with:

- enhanced productivity and nutrient use efficiency,
- more efficient weed management and increased biodiversity, but
- lower carbon footprints (in particular increased carbon sequestration and lower GHG emissions from soils)."

Project coordination: Paul Mäder, FiBL

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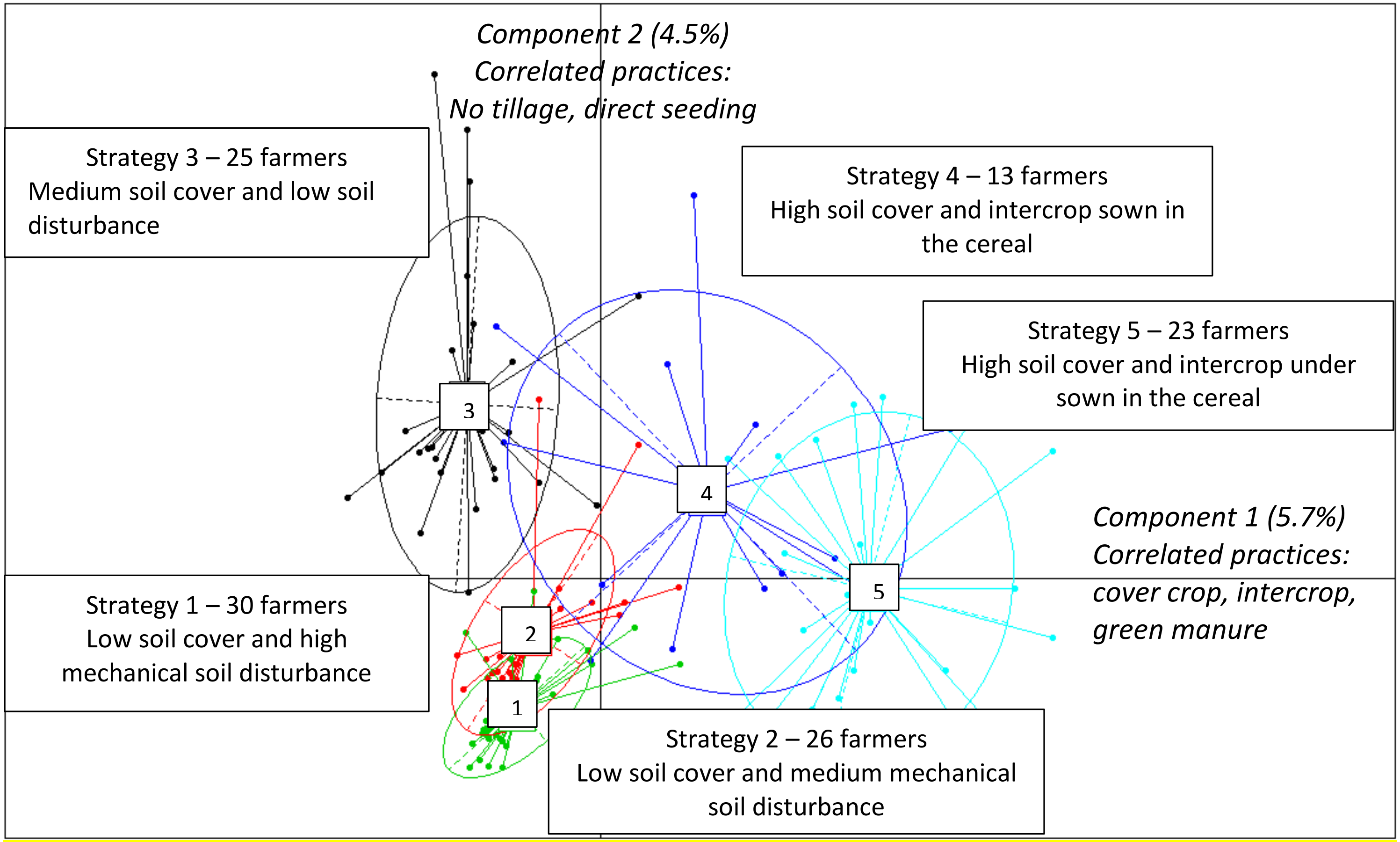
Farm survey: Distribution of strategies of winter cereal management



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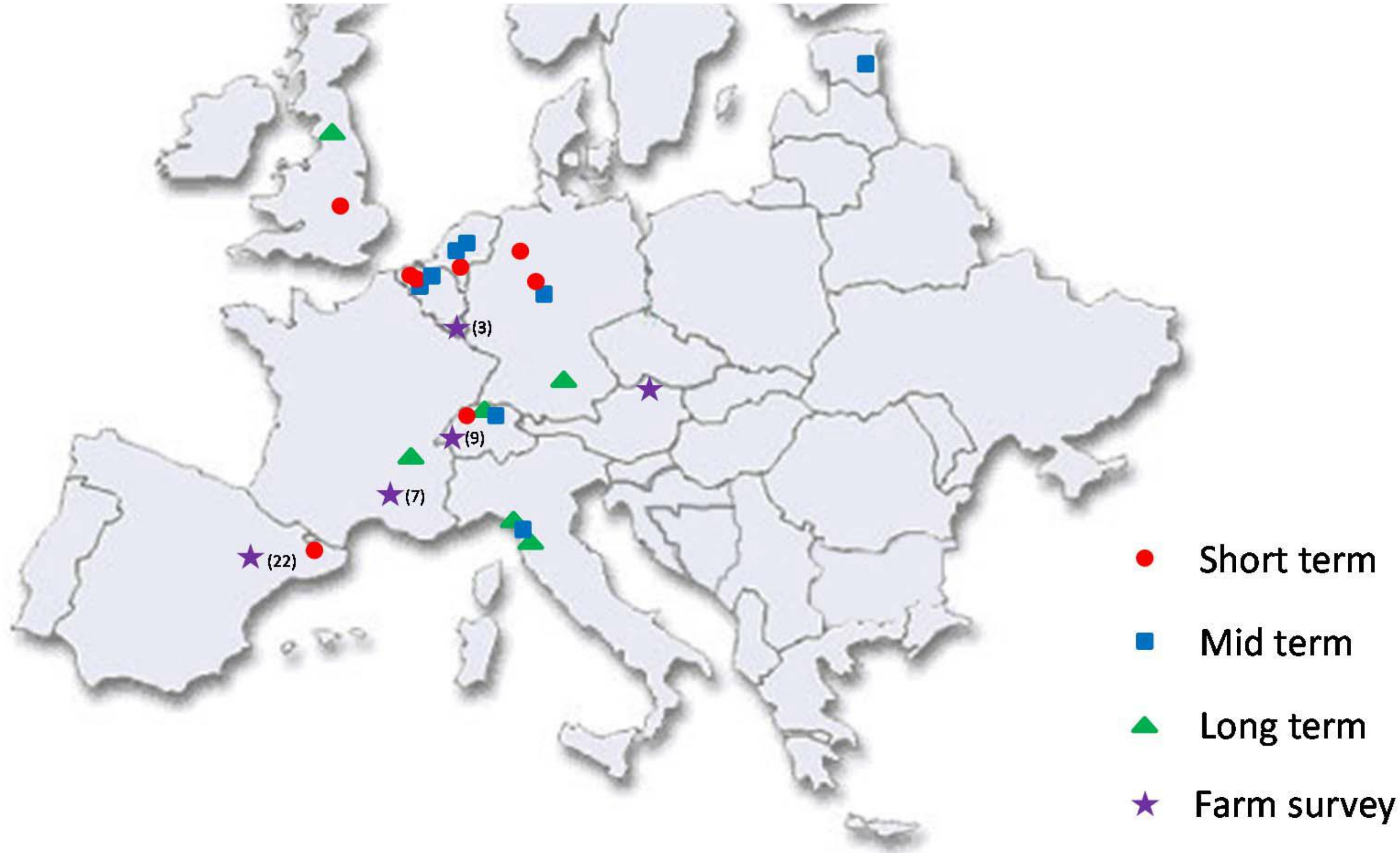
Peigné, Casagrande, Payet, David, Mäder et al., accepted, Renewable Agriculture and Food System

Field trials and farm surveys under investigation in the European network TILMAN-ORG



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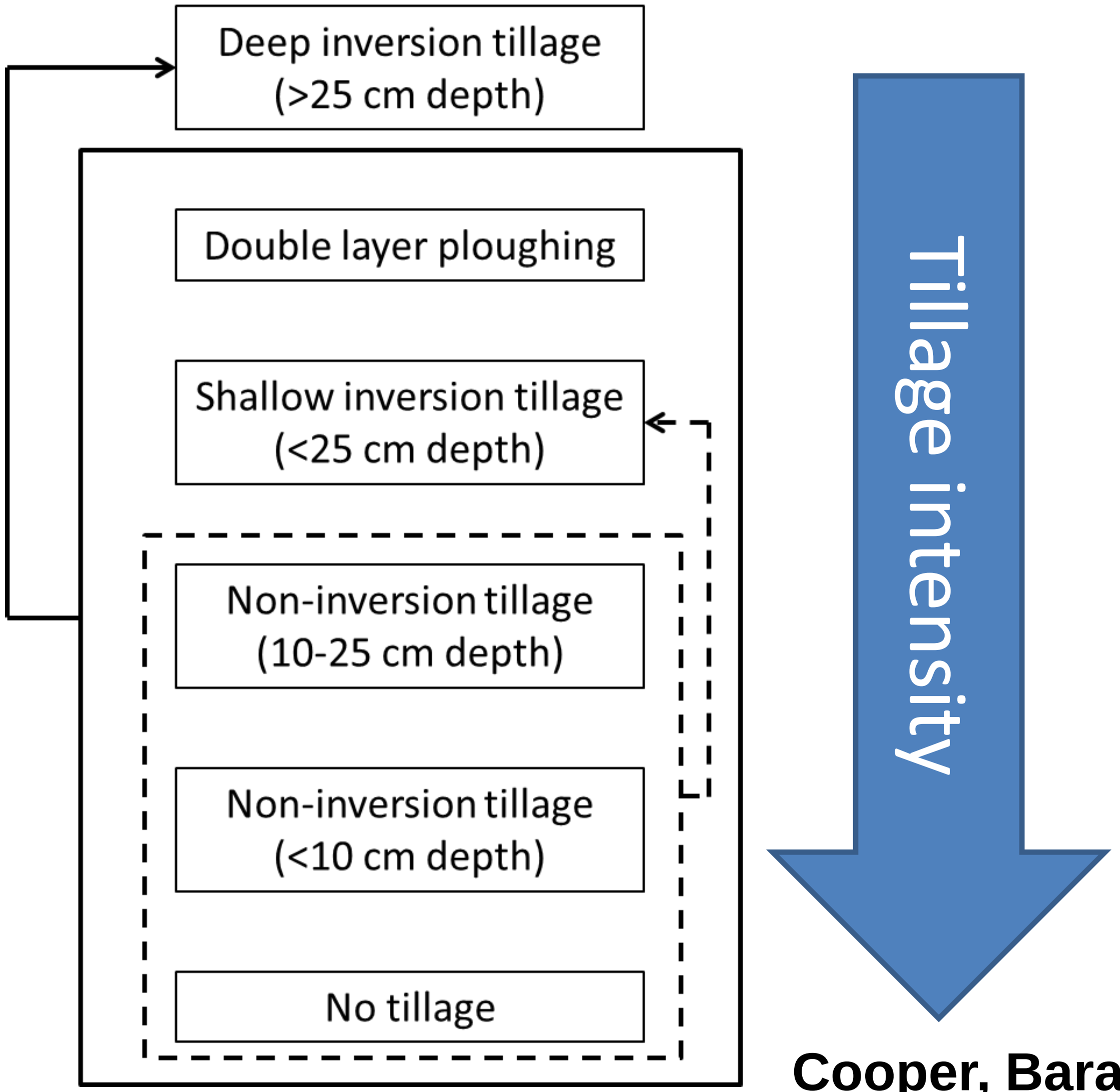
Meta-analysis: Classification of tillage treatments



Row data from 15 experiments

Including literature 58 studies Europe & Canada

Cooper, Baranski, Nobel de Lange, Peigné, Fliessbach, Mäder et al., unpublished

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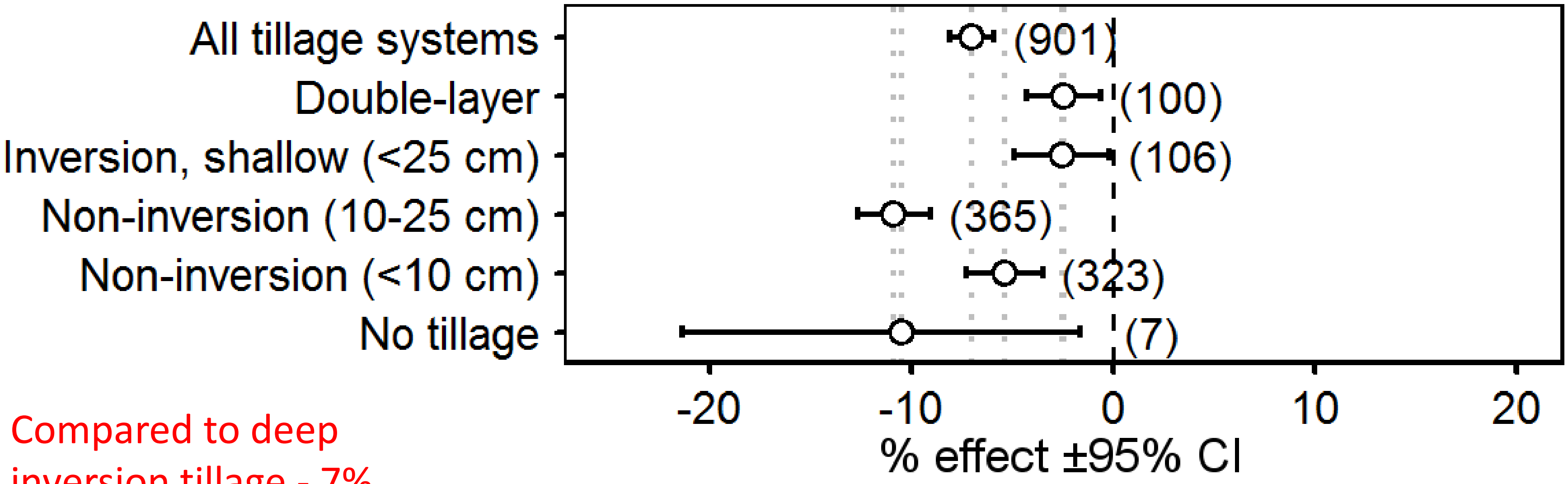
Yields - compared to deep inversion

What is the magnitude of the effect of reduced tillage intensity on crop yields in organic systems?



Compared to deep inversion tillage - 7% reduction on average

Deep non-inversion – greatest yield reduction ~ 11%

Shallow inversion shows no significant yield reduction – 2.6%

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Cooper, Baranski, Nobel de Lange, Peigné, Fliessbach, Mäder et al., unpublished

Yields - compared to shallow inversion

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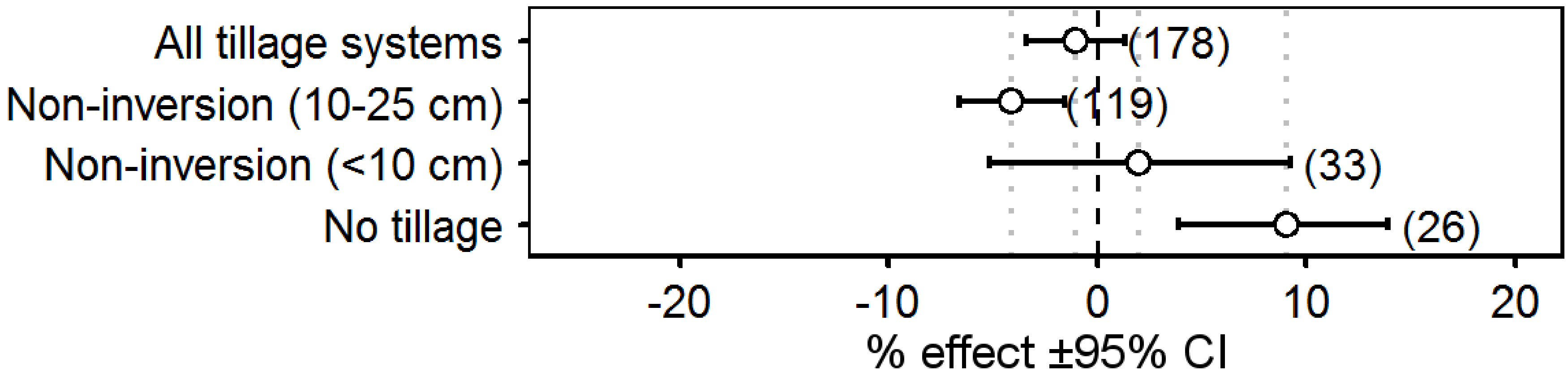

Compared to shallow inversion –
no yield reduction

No tillage increases yields! Why?

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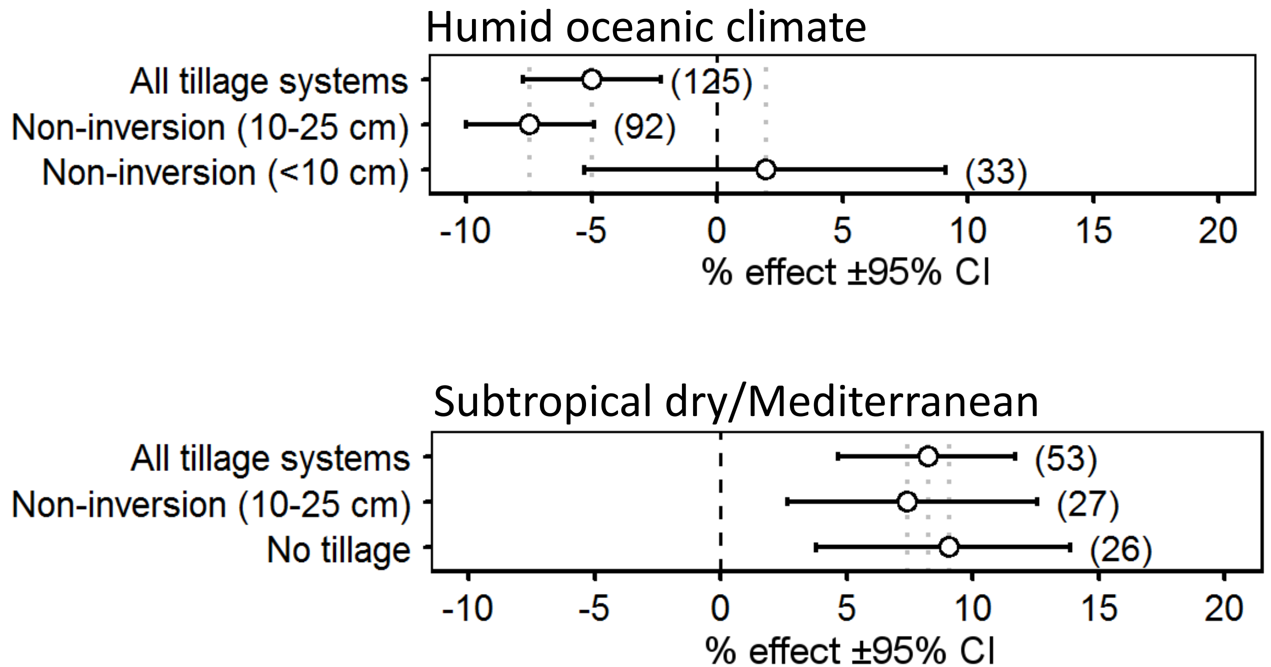
Cooper, Baranski, Nobel de Lange, Peigné, Fliessbach, Mäder et al., unpublished

Yields – in different climatic zones

Is this effect consistent across all environments (soil types and climatic zones)?



Reduced tillage intensity
is particularly beneficial
in dry climates

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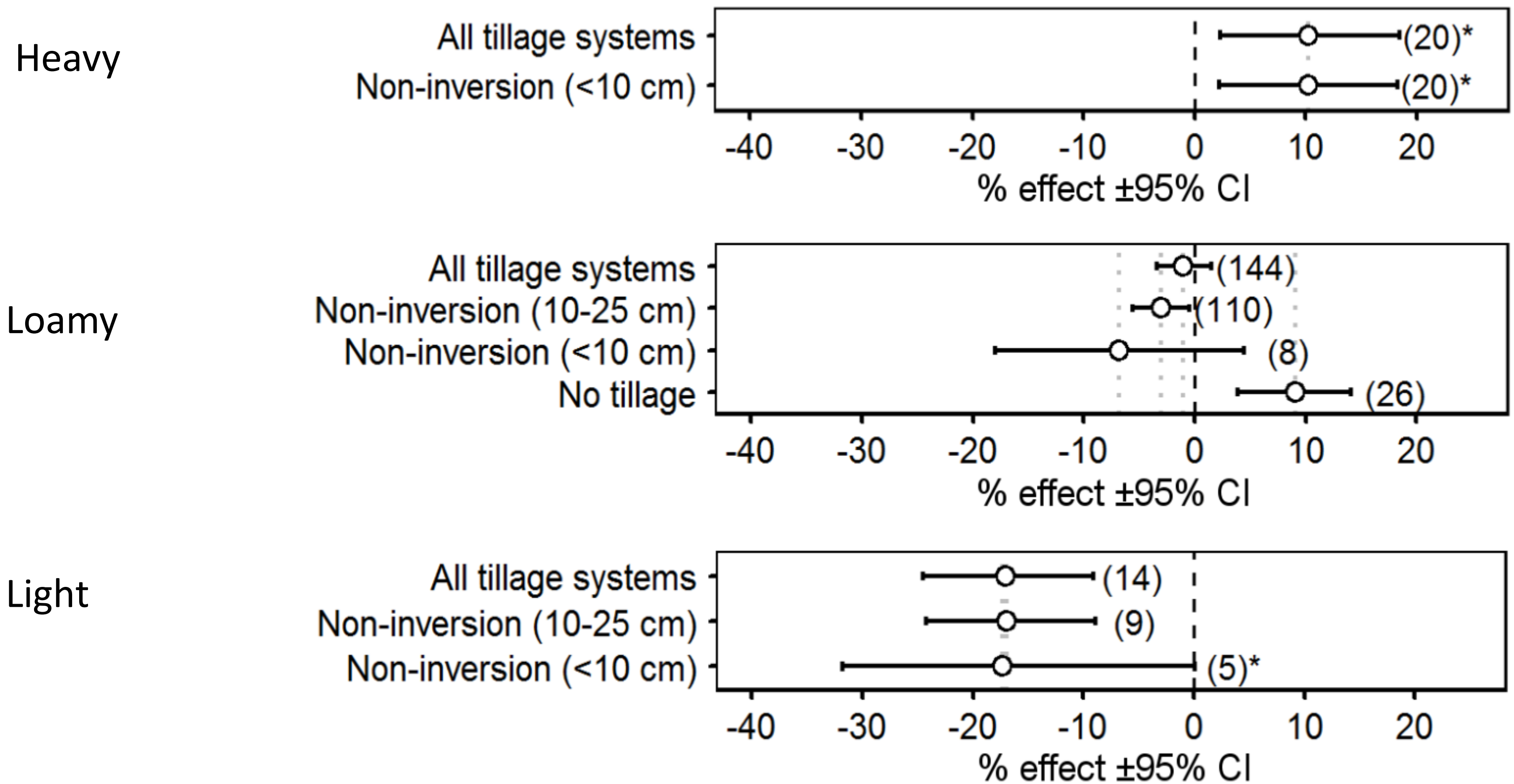
Cooper, Baranski, Nobel de Lange, Peigné, Fliessbach, Mäder et al., unpublished

Yields – effect of soil type

Is this effect consistent across all environments (soil types and climatic zones)?



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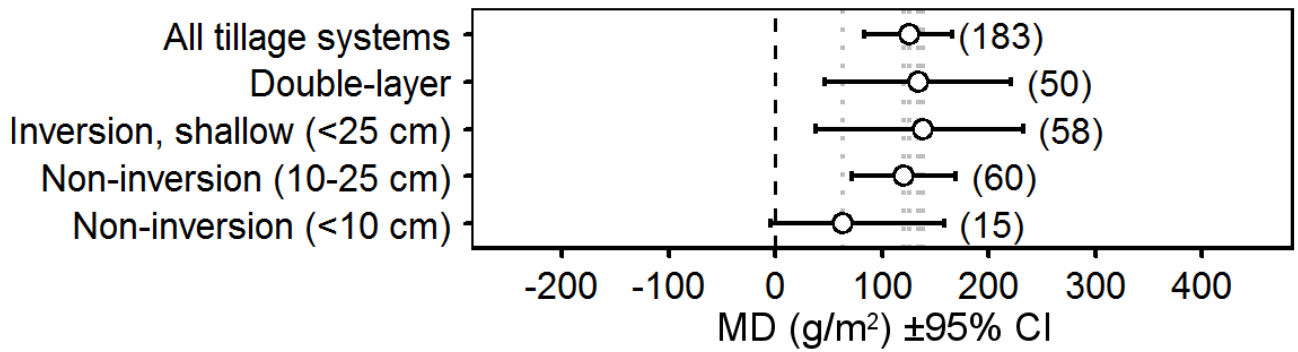
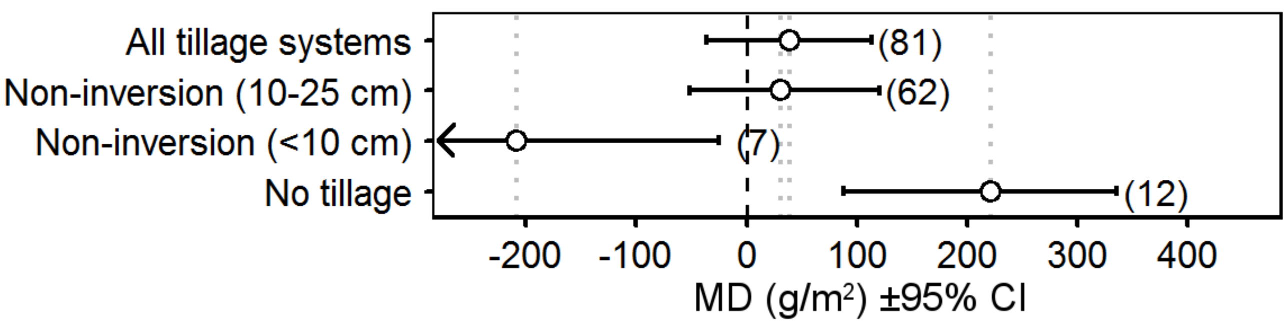
Cooper, Baranski, Nobel de Lange, Peigné, Fliessbach, Mäder et al., unpublished

Carbon as affected by tillage

Does using reduced tillage in organic systems increase soil organic C above the levels already achieved by organic practice?



Yes, relative to deep inversion



In some cases, relative to shallow inversion

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Cooper, Baranski, Nobel de Lange, Peigné, Fliessbach, Mäder et al., unpublished

Key findings Meta Analysis

- Yield reductions from reducing tillage intensity can be quite small or non-existent depending on the system and environment
- Converting to shallow inversion tillage from deep inversion – minimal yield reductions, significant C gains, if weeds are controlled
- Weed pressure is not the only factor driving yield reductions under reduced tillage
- Particular benefits to reducing tillage intensity in dry climates – water relations?
- Challenges in light soils – compaction?

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Cooper, Baranski, Nobel de Lange, Peigné, Fliessbach, Mäder et al., unpublished

Case study: Reduced tillage and cover crops in organic arable systems preserve weed diversity without jeopardising crop yield

- Ploughing to be phased out in organic farming?
- Conservation agriculture (CA) in organics
  - Where do we stand with weed management?

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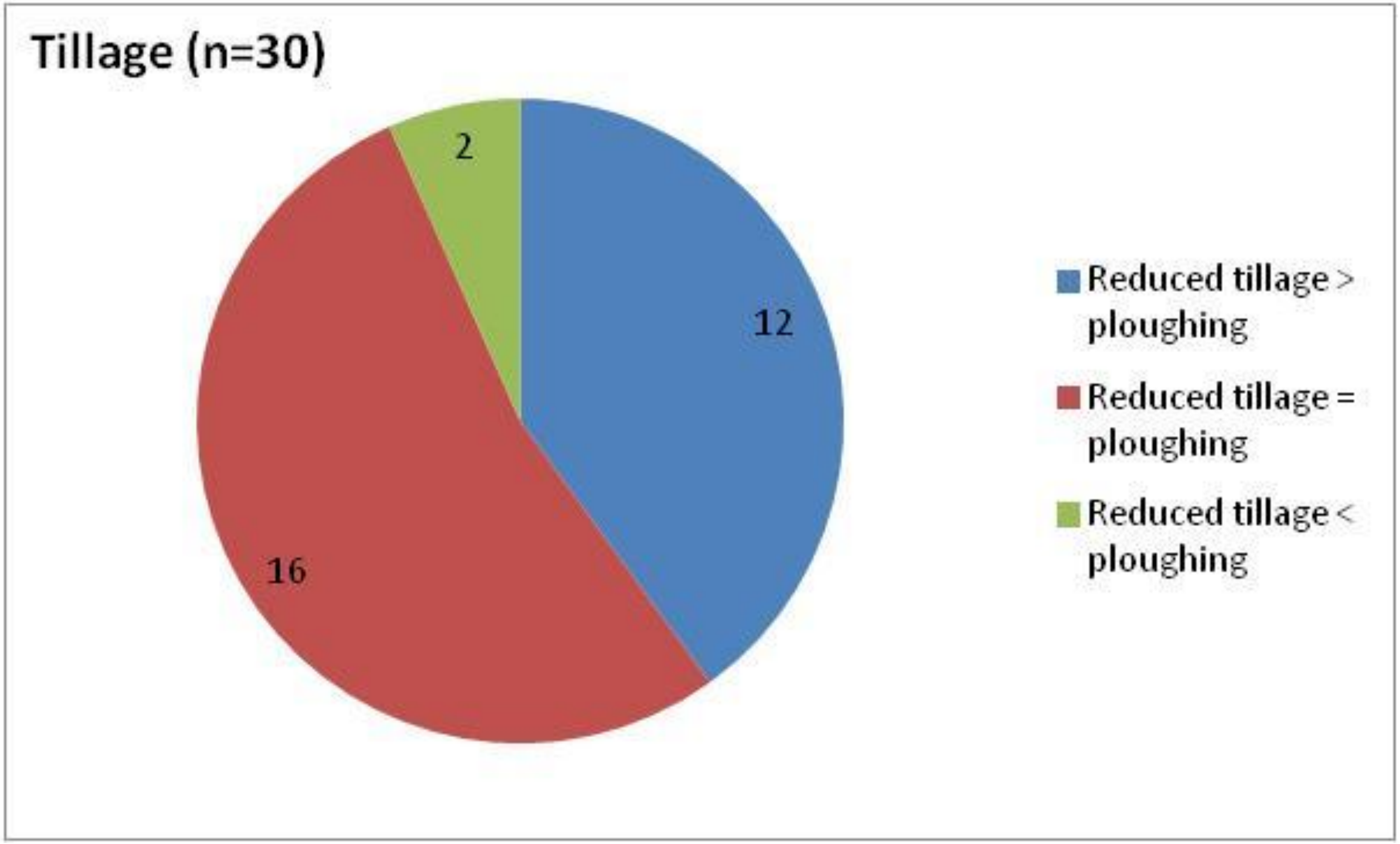
Scuola Superiore Sant'Anna
di Studi Universitari e di Perfezionamento

Bàrberi et al., SSSA, unpublished

Weed abundance



PLO < RED *vs* PLO ≥ RED: **P = 0.273ns** (χ^2 test, df=1)

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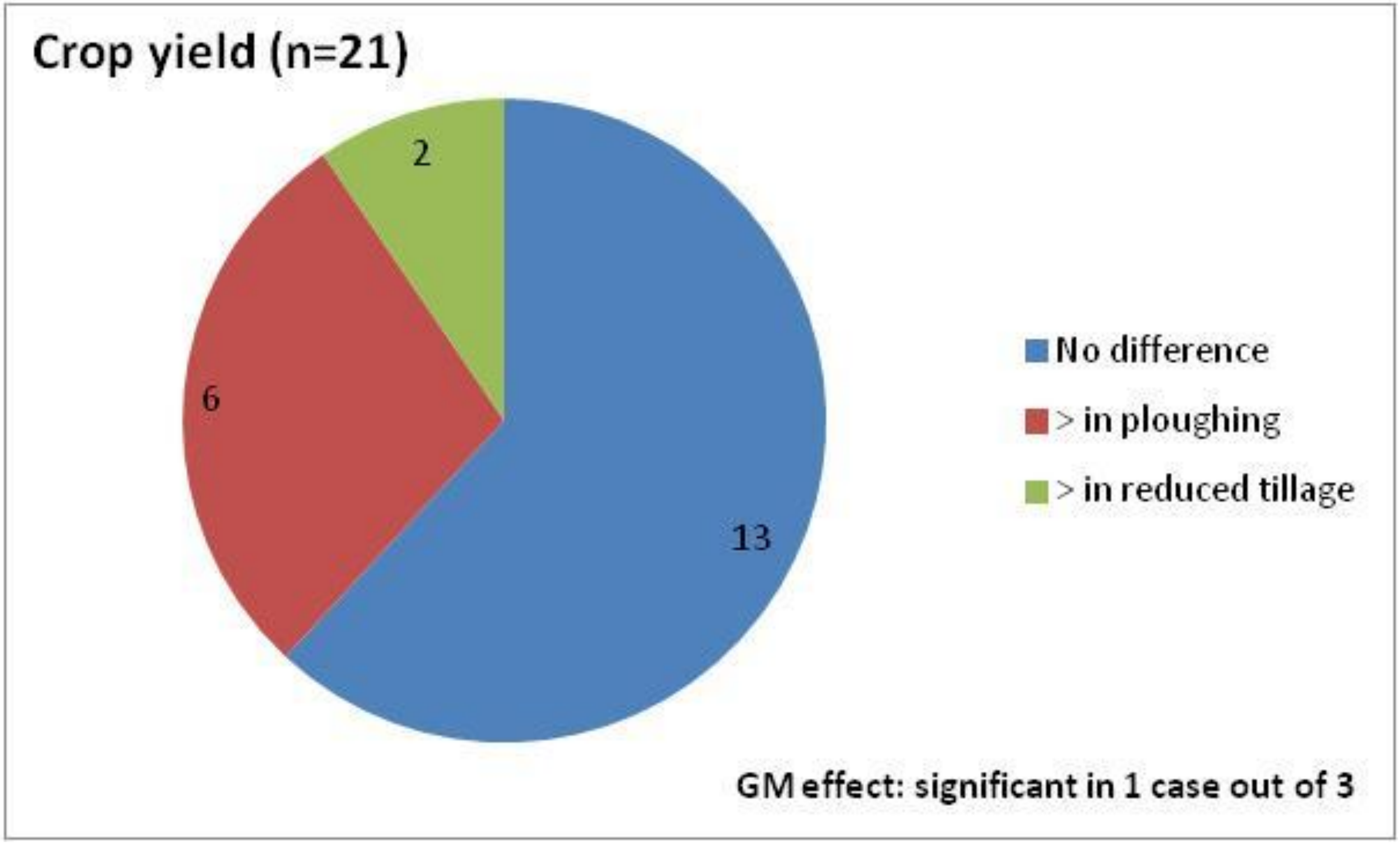
Bàrberi et al., SSSA, unpublished

Crop yield



PLO > RED *vs* **PLO ≤ RED**: **P = 0.049*** (χ^2 test, df=1)

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Bàrberi et al., SSSA, unpublished

Case study: Yield, mineral nitrogen in spring (N-min), nitrogen use efficiency (NUE) and N surplus (N-surplus) 9 experiments

	Tillage			Green Manure (GM)		
	plough	RT	p	-GM	+GM	p
Yield [% of control (RT, -GM)]	100	92	<0.001	100	108	0.001
N_{min} [% of control (RT, -GM)]	100	85	<0.001	100	128	<0.001
NUE [%]	182	129	<0.001	278	169	0.002
N-surplus [kg N ha^{-1}]	10	23	0.098	-4	37	<0.001

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Koopmans et al., LBI, submitted

Case study: The organic long-term tillage trial in Frick, Switzerland

- Since 2003
- Strip split-plot design
- 6 years crop rotation
- Heavy clay soil (Cambisol, Ø 50 % clay)
- Ø 1000 mm, 9 ºC

- Tillage
  - Plough (CT, 15 cm)
  - Reduced tillage (RT, 10 cm)
- Fertilisation
  - Diluted slurry only (SL)
  - Manure compost/slurry (FYM)
  - Ø N input 2013: 113 kg Nt ha^{-1}

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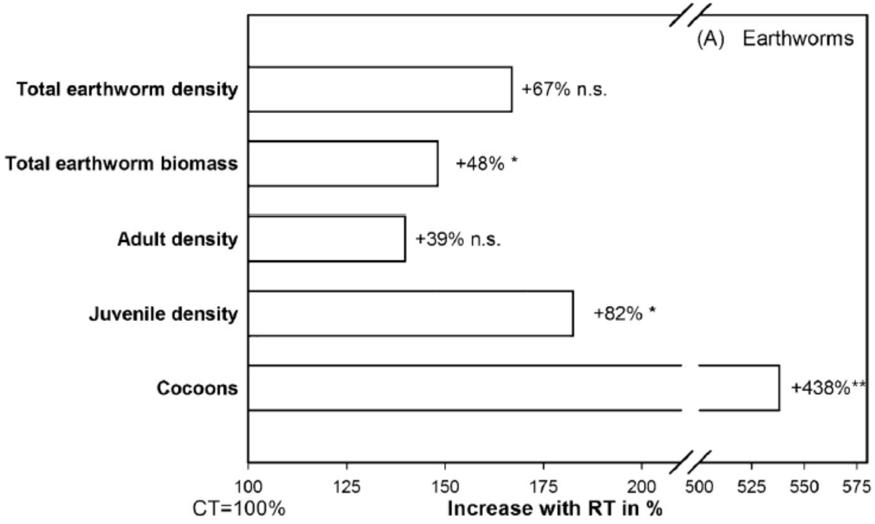
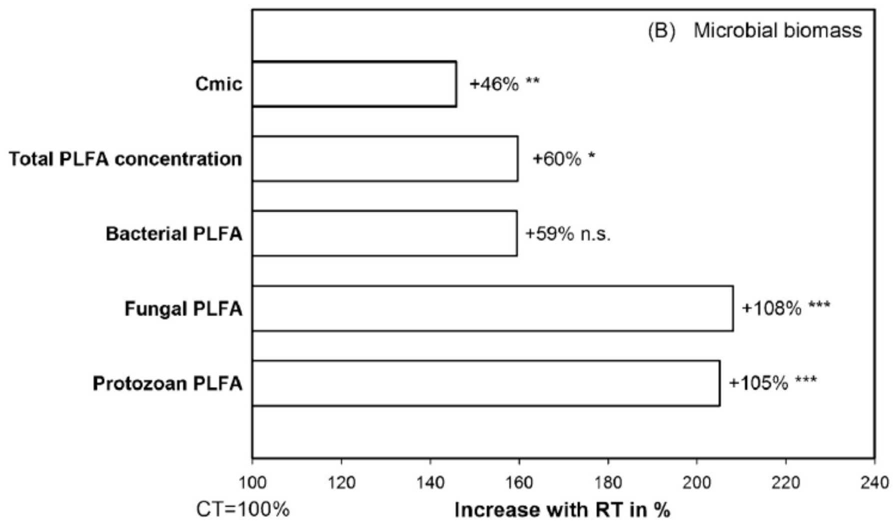
Relative impact (in percent) of reduced tillage on earthworm and microbial biomass





Conventional tillage (CT) = 100%)

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Kunz et al., 2013, Pedobiologia

Greenhouse gas fluxes influenced by tillage

Van Kessel et al. (2013)

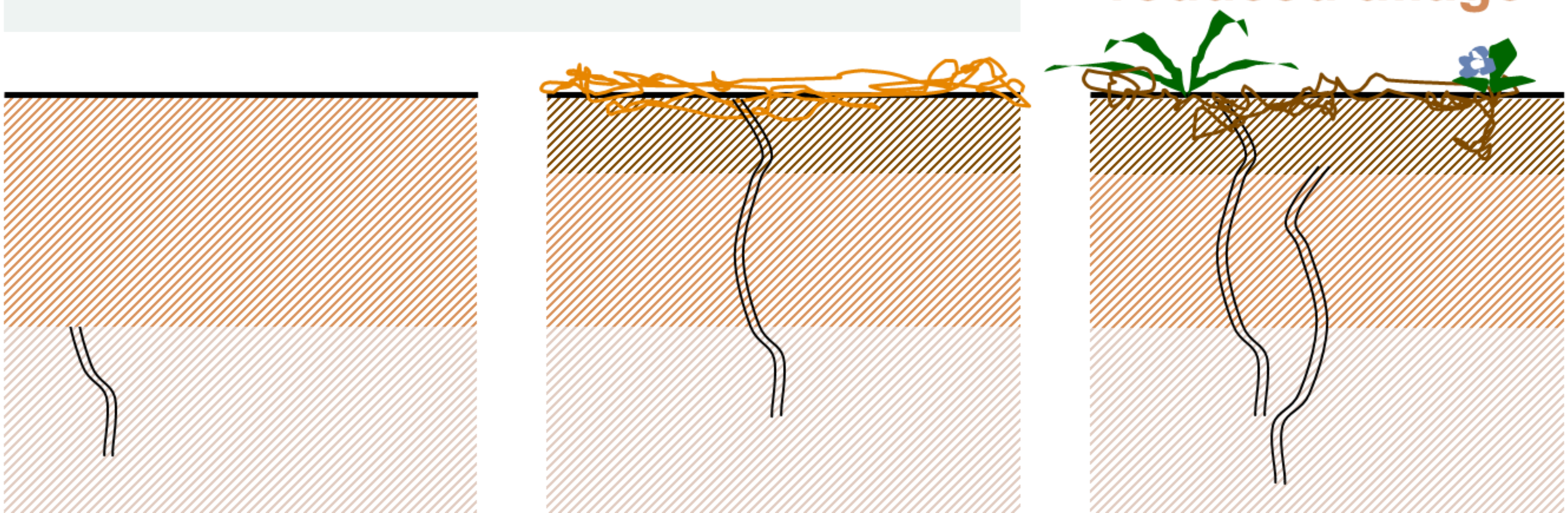
- No difference in N_2O emissions after 10 years in temperate regions

ploughing

no-till with herbicides

organic reduced tillage

?



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Cumulative nitrous oxide emissions

Table 1. Least square means of cumulative N_2O flux rates per treatment for the grass-clover (18/09/12 – 20/09/13) and ley destruction (22/09/13 – 21/11/13) period

	Grass-clover (1 year)				Ley destruction (2 months)
	N_2O-N	GWP in CO_2-eq.		EF*	N_2O-N
	kg ha^{-1}	area: kg ha^{-1}	yield: kg t^{-1} DM	%	kg ha^{-1}
CT	0.95	445.3	39.1	0.86	1.04
RT	0.98	459.5	42.8		1.34
FYM	0.88	412.0	38.6		1.42
SL	1.05	492.9	43.4		0.96
RT/CT	103 %		110 %		128 %
SL/FYM	120 %		113 %		68 %
Tillage	ns	ns	ns		ns
fertilisation	ns	ns	ns		p = 0.041
tillage x fertilisation	ns	ns	ns		ns

*EF = emission factor (kg N_2O–N / kg N input × 100), biol. fixed clover N was excluded
Trial treatments: CT = ploughing, RT = reduced tillage, FYM = farmyard manure/slurry, SL = slurry only

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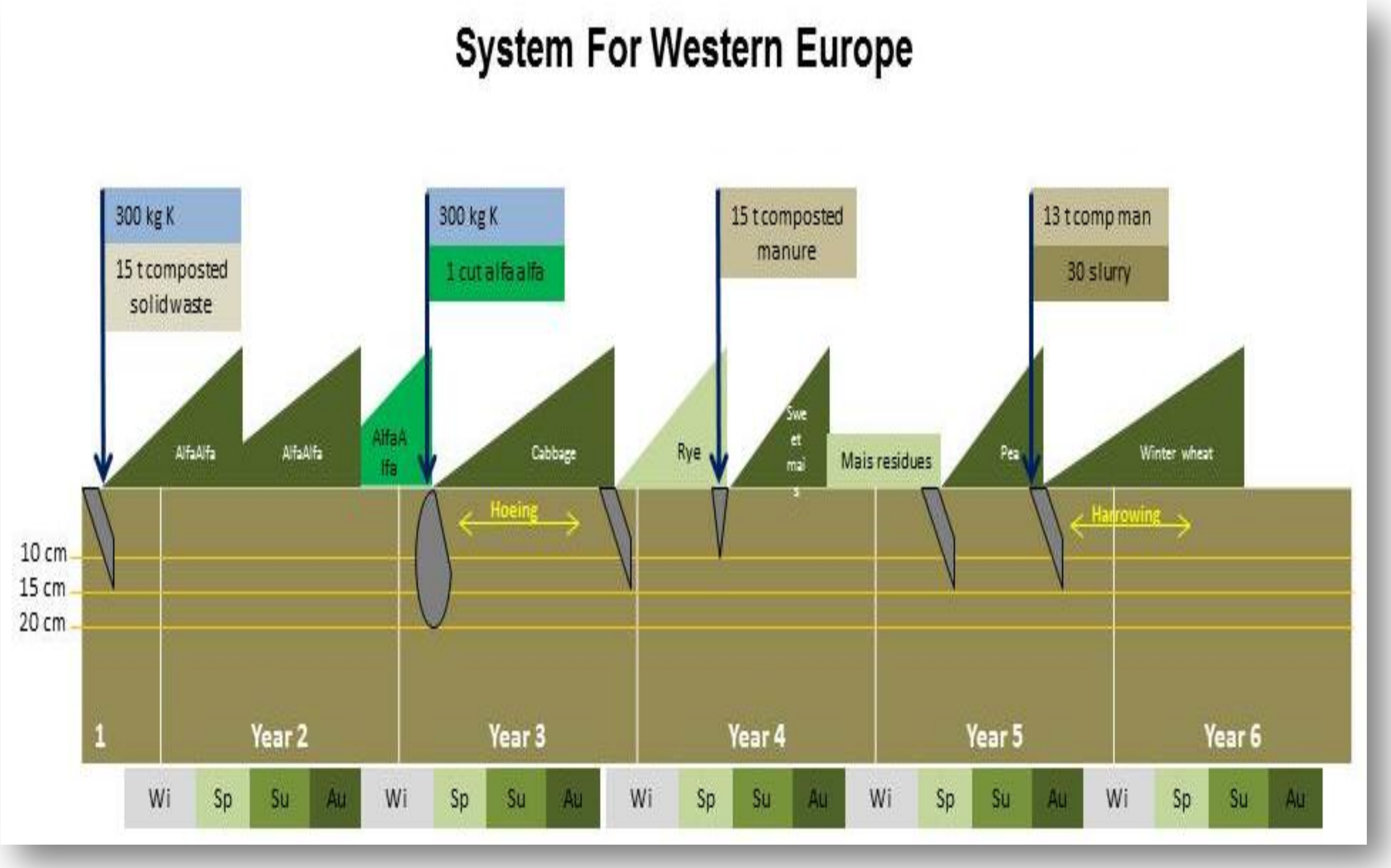
Kraus et al., FiBL, unpublished

Farm prototyping



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Casagrande, Peigné, David, et al, ISARA

Strengths and Weakness of : (1) conservation tillage systems versus conventional tillage (ploughing) in 5 long-terms experiments and (2) between green manure with mixed, legumes and non-legumes species in 1 long-term experiment

Conservation tillage vs. ploughing	Strengths	Weakness
Frankenhausen – WIZ	Macrofauna conservation (in biodiversity conservation)	Control of weeds, pest and disease (in long-term ability to produce)
Broekemahoeve-BASIS – WUR	Macrofauna, micro fauna and flora conservation (in biodiversity conservation) Environmental quality	Control of weeds, soil structure (in long-term ability to produce)
THIL – ISARA Lyon	Macrofauna, micro fauna and flora conservation (in biodiversity conservation) Environmental quality	Control of weeds, soil structure, P and K fertility in (long-term ability to produce) Economic results (direct seeding)
HMGU-org 3 (Sheyern) – HMGU	Micro fauna conservation P and K fertility (if high fertilization)	Soil structure, Economic results (but just little bit lower than conventional)
Frick – Fibl	Macrofauna and micro fauna conservation (in biodiversity conservation)	Control of pest and diseases (in long-term ability to produce)
Green manure (legumes, mixed and non-legume)	Strengths	Weakness
MASCOT – CIRAA	Biodiversity conservation with non-legume green manure	P and K stress with mixed green manure (in long-term ability to produce)

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Peigné, et al., ISARA, unpublished

Conclusions

- Reduced tillage in organic farming is a viable option to ascertain vital ecosystem functions:
  - Yield
  - Maintenance biodiversity
  - Soil quality
  - Climate mitigation?
- Major research questions for the future
  - Weed control
  - Hybrid systems
  - In-depth knowledge on microbial processes of N-cycle
  - Interactions soil biological and soil physical parameter

Acknowledgements

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Supplemental materials

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Data sources meta-analysis

- Raw data from 15 experiments; project partners and others; European and Canadian
- Data from literature and raw data combined – 58 studies
- Criteria:
  - experiment under organic management for at least three years prior to the date of response measurement
  - at least two levels of tillage intensity included as a treatment
  - no “mixing” of treatments i.e. only tillage varied between experimental treatments
  - included climatic zones found in Europe

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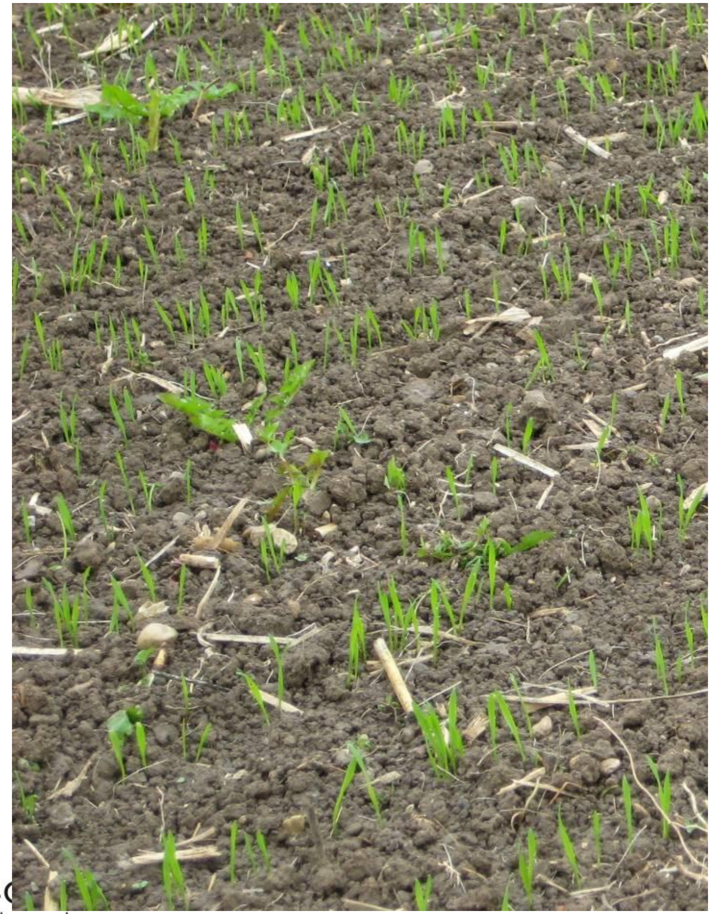
Cooper, Baranski, Nobel de Lange, UNEW, et al., unpublished

Soil structure

October 27th 2008

Reduced tillage



Plough

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