Managing the Soil - The Science of Soil

Paula Misiewicz,
colleagues and students

pmisiewicz@harper-adams.ac.uk




Outline

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1. The importance of soil.
2. The impact of poor soil/vehicle management in terms of soil compaction.
3. Reducing the impact of farm vehicles on compaction.
4. The effect of the above on soil and crop yields.
5. Conclusions and recommendations for further work.

The Importance of Soil

- Healthy soil is the foundation of the food system
- 99% of global calorific demand is met by food from soil

  (FAO, 2014)
- More than 75 % of soils globally are classed as substantially degraded

  (Scholes et al., 2018)
- “A nation that destroys its soil destroys itself”

  (Roosevelt, 1937)

How Much Water is There?

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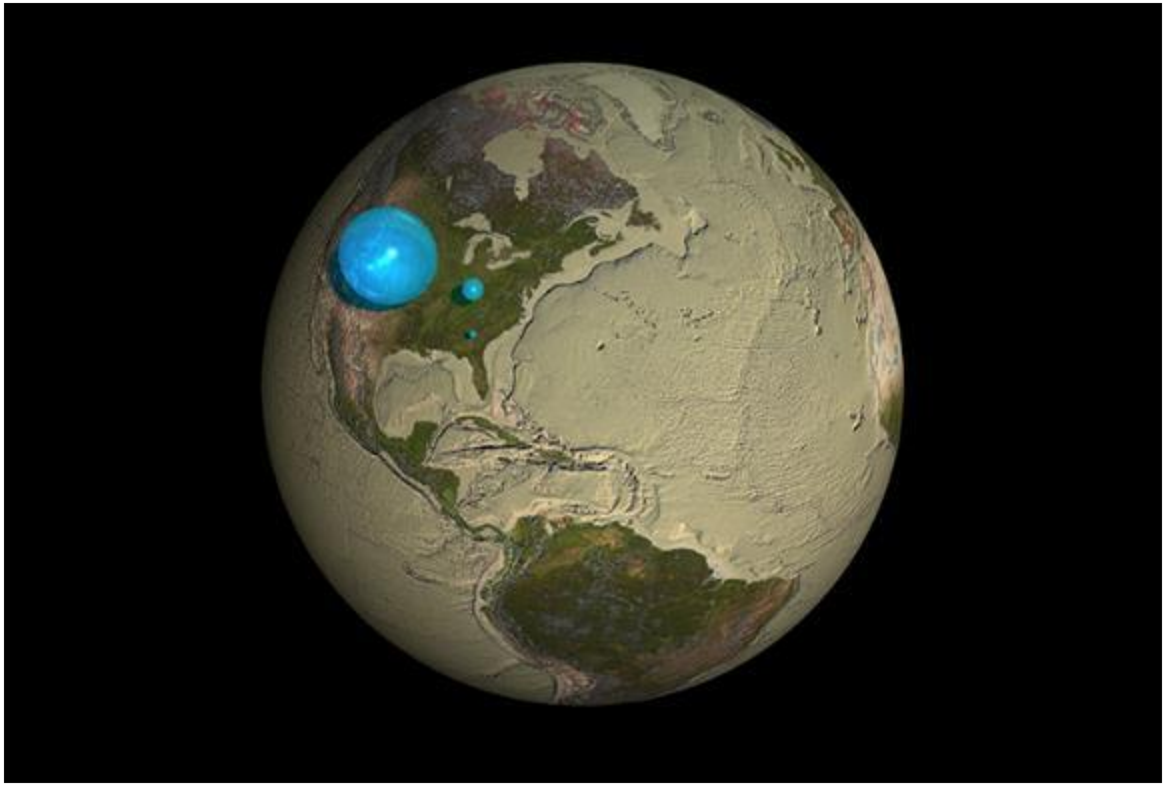


Source: Howard Perlman and Jack Cook

How Much Fertile Soil is There?

- According to FAO 4.2 billion hectares used for agriculture (other estimates range from 1.6 billion to 3.6 billion)

- Assuming average top soil depth of 20 cm

- Volume of soil = 8,400 km^3

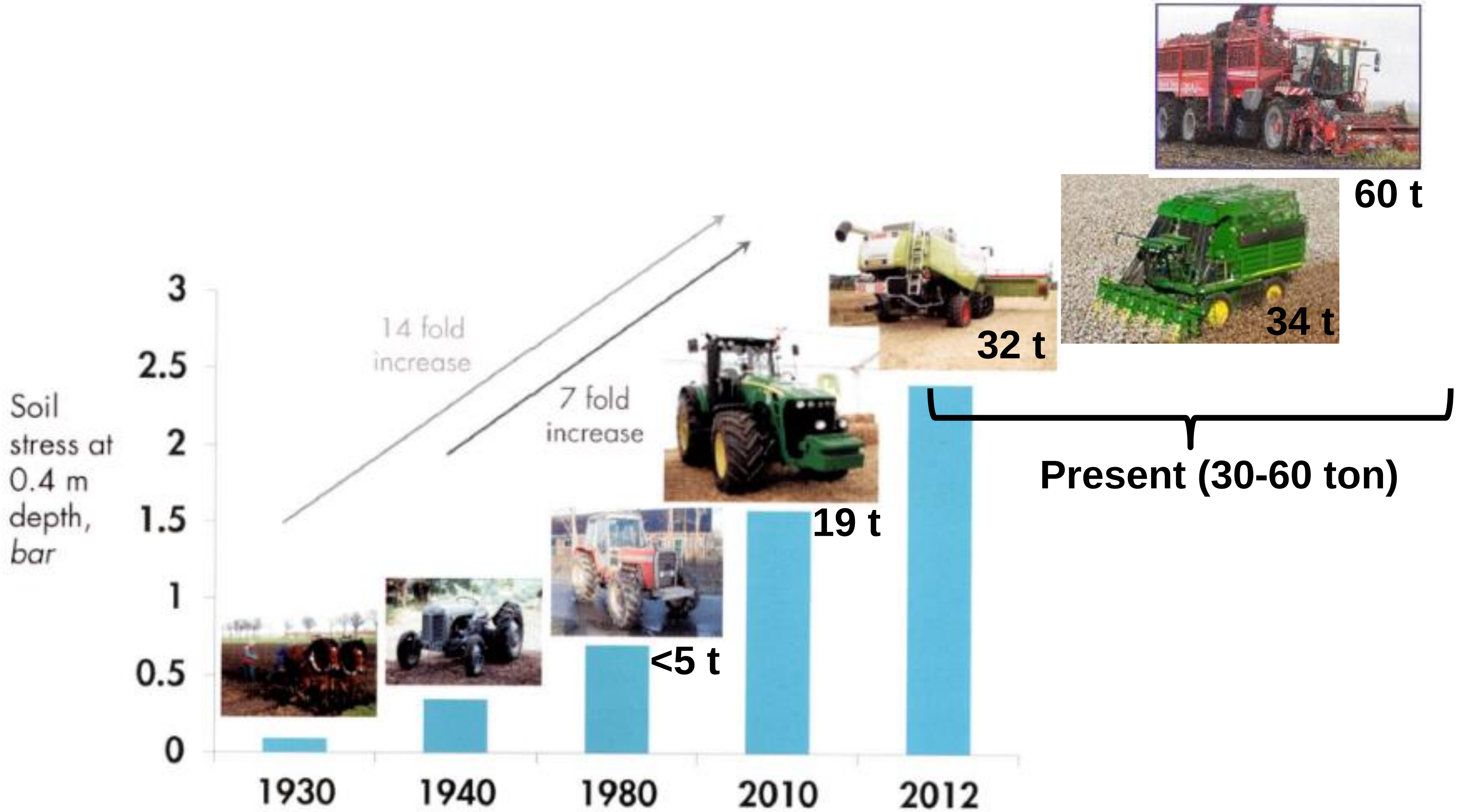
Source: Jeffery (2022)

How Much Soil is That?

Sphere 25 km in diameter

Source: Jeffery (2022)

The problem: increased axle loads coupled with ‘random’ (non-controlled) traffic



Loads keep increasing - and with them, danger of subsoil damage

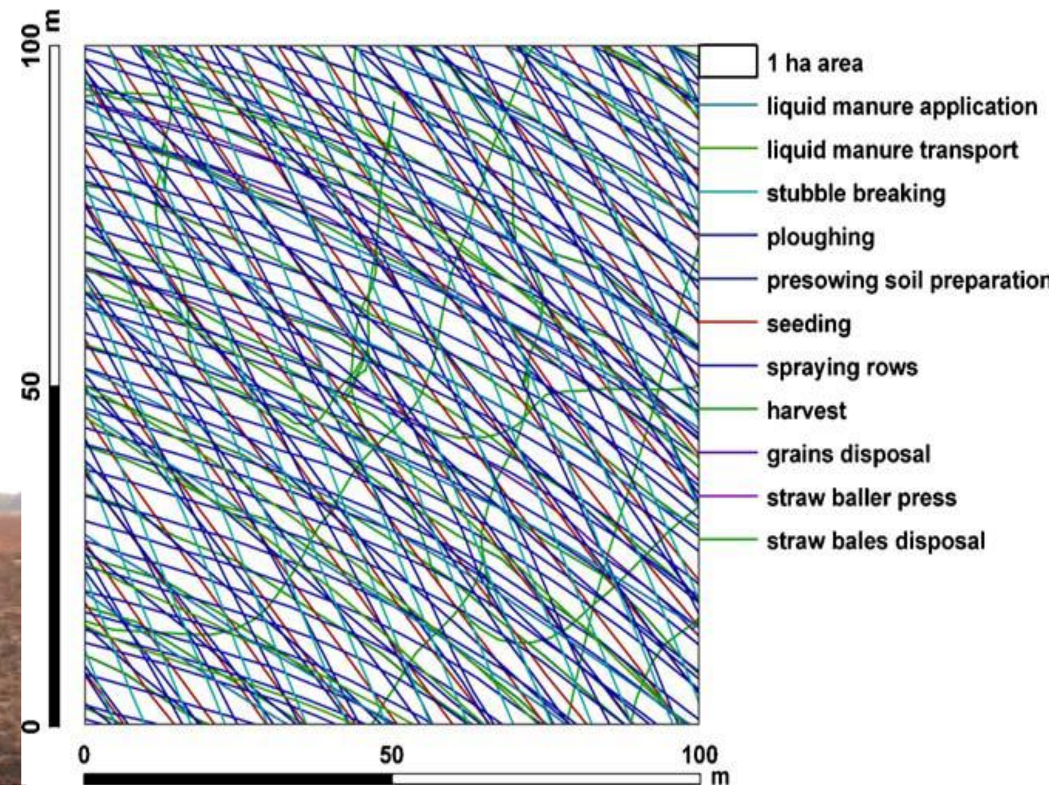
Random* traffic problems

*Un-controlled traffic

Extensive areas of the field are exposed to trafficking

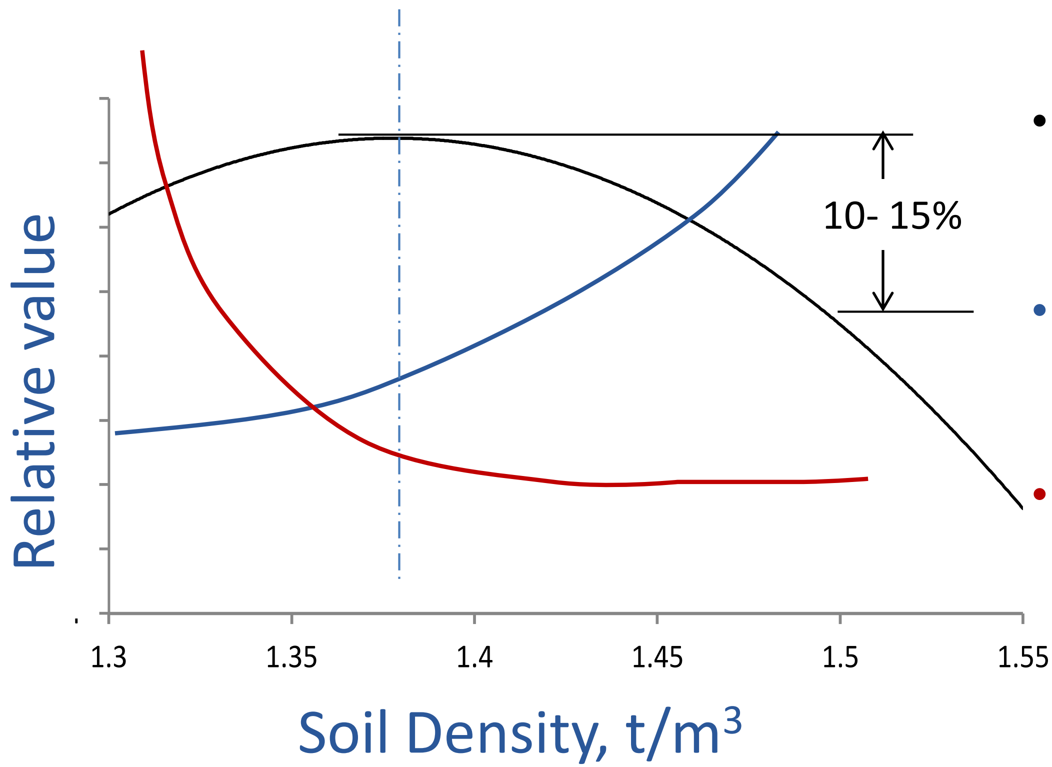
- Plough Based Tillage= 85% covered
- Minimum Tillage = 65% covered
- Zero/No Tillage = 45% covered

Winter wheat – Czech Republic



Kroulik et al., 2009

The effects of soil compaction



- Reduces crop yield from optimum *(Negi & McKyes, 1978)*
- Increases tillage draught forces *(Godwin, 1974; Chamen et al, 1992)*
- Reduces infiltration rates *(Chamen 2011; Chyba, 2012)*

Economic cost in England and Wales :
£1 bn/annum

(Morris et al - Cranfield University, 2011)

Impact of traffic on soil porosity

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Before traffic

After traffic

Large, vertically-oriented drainage pores more affected, lesser effect on microporosity

Pores' connectivity is significantly disrupted

(After Schjønning et al., 2013)

Options for compaction reduction

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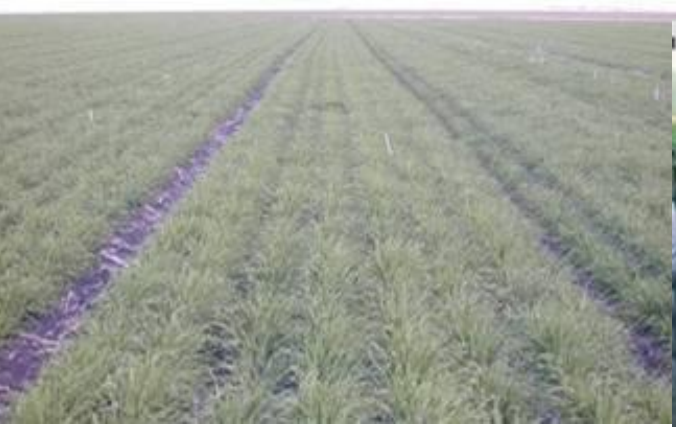
Tracks/reduced inflation pressure/autonomous low mass vehicles

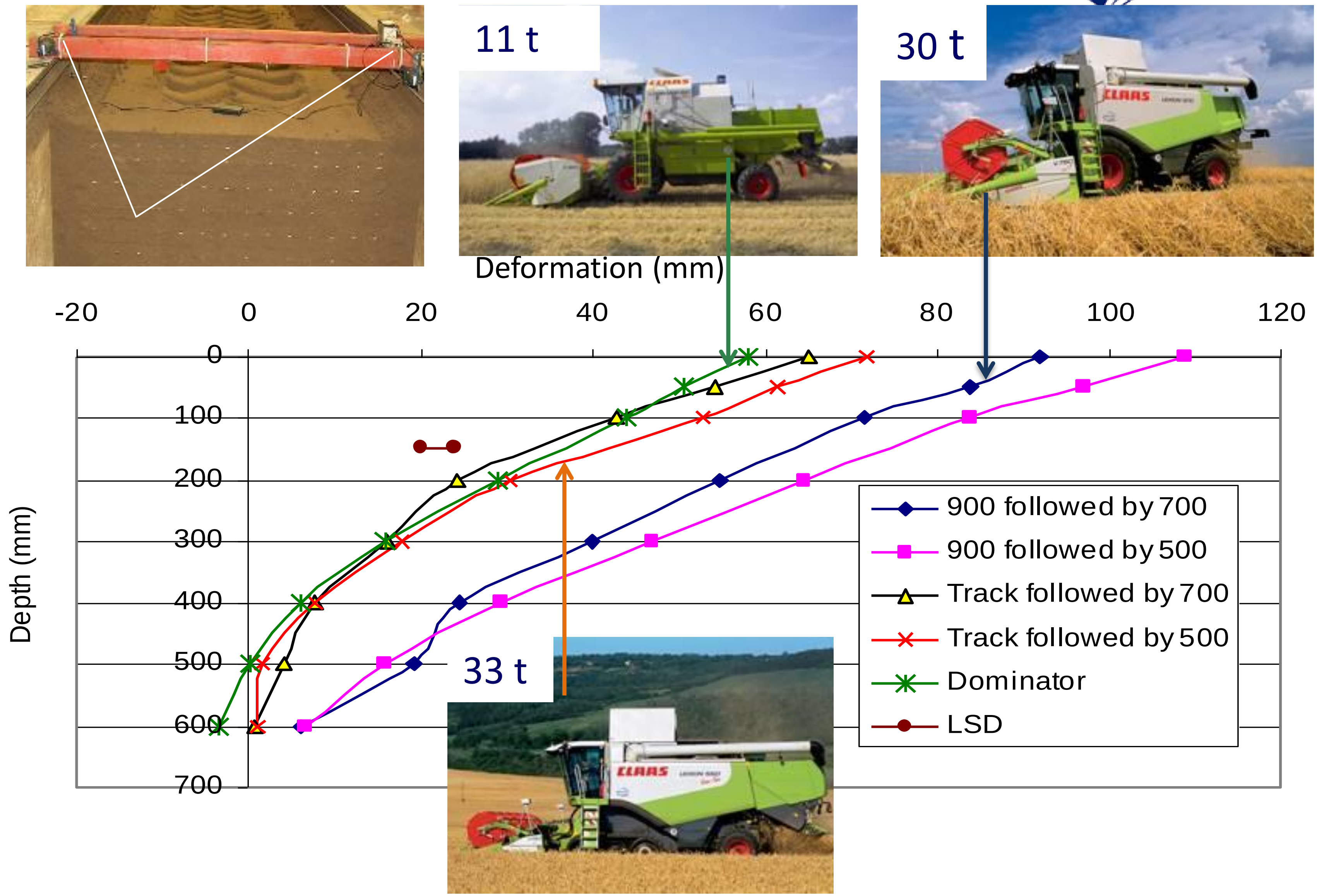
Controlled traffic



After: Tullberg et al. 2003

Source: CTF Europe

Rubber tracks



Ansorge, D. and Godwin R. J., 2007, The effect of tyres and a rubber track at high axle loads on soil compaction, Part 1: Single axle-studies. Biosystems Engineering, 98(1)

Controlled traffic farming (CTF)

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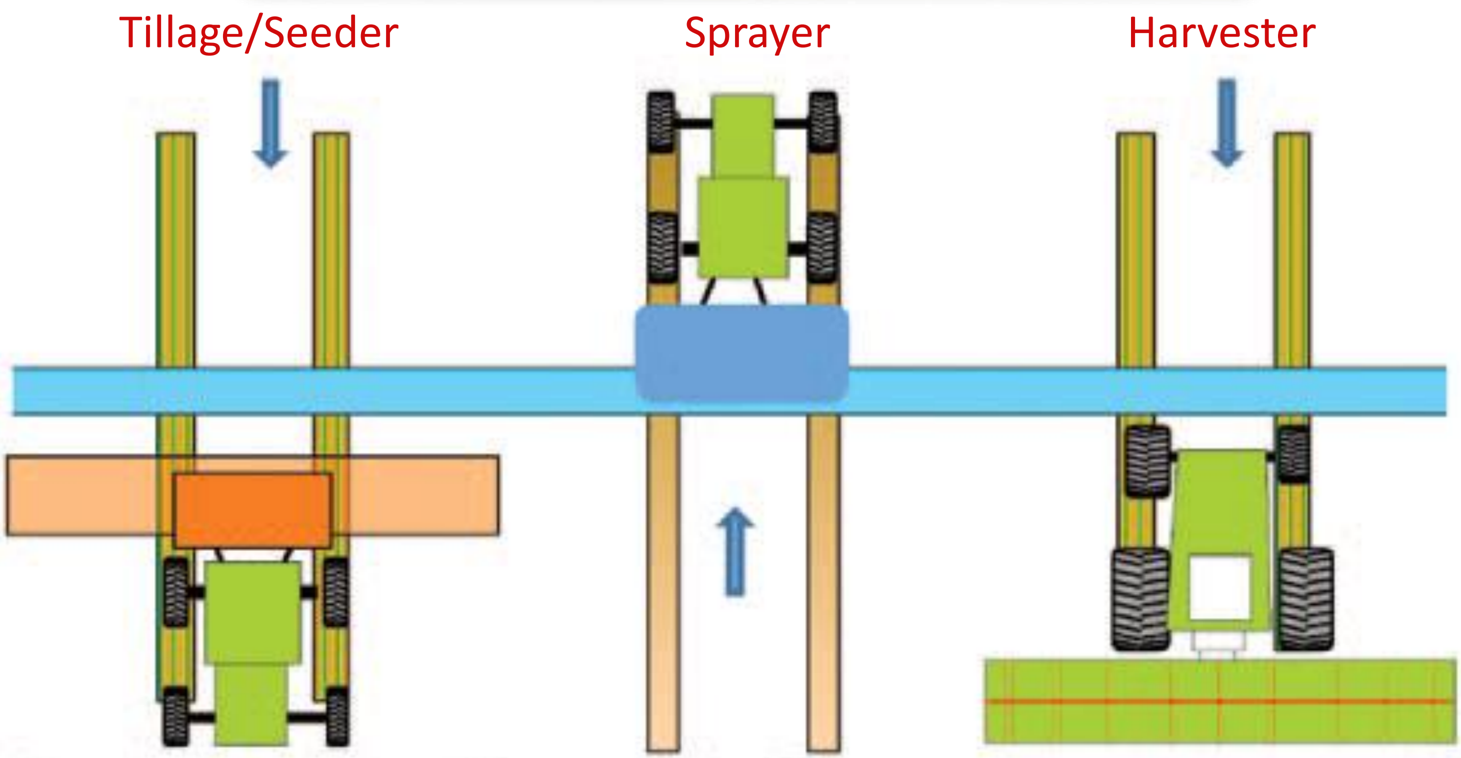
Area exposed to wheels < 30% & could be 15%. Maintains soil structure

Chamen, CTF Europe



Traffic and Tillage Systems Shropshire, England

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Sandy loam soil

2011 - 12: Winter Wheat (normalisation year)
2012 - 13: Winter Wheat
2013 - 14: Winter Barley
2014 - 15: Winter Barley
2015 - 16: Cover crop & Spring Oats
2017 - 17: Spring Wheat
2017 – 18: Winter Beans
2018 - 19: Winter Wheat
2019 - 20: Winter Barley
2020 - 21: Winter Barley
2021 - 22: Cover crop & Millet

3 x 3 factorial design

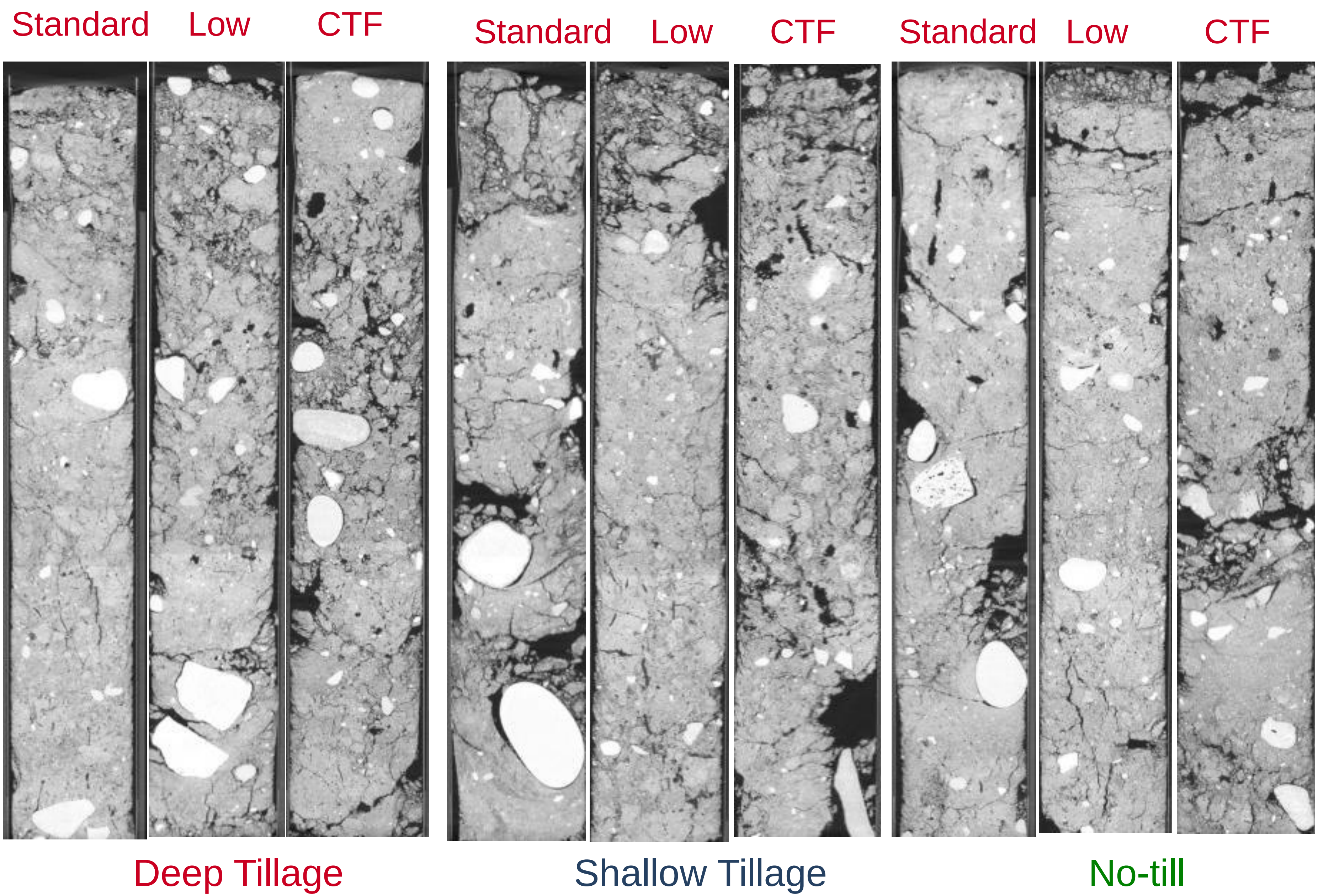
9 treatments replicated in 4 blocks
= 36 plots in total (each 4m wide)

Traffic / Tillage	Standard Tyre Pressure	Low Tyre Pressure	Controlled Traffic Farming
Deep tillage	250mm	250mm	250mm
Shallow tillage	100mm	100mm	100mm
Zero/No tillage	0mm	0mm	0mm

After: Smith, Misiewicz, Chaney, White and Godwin, 2014

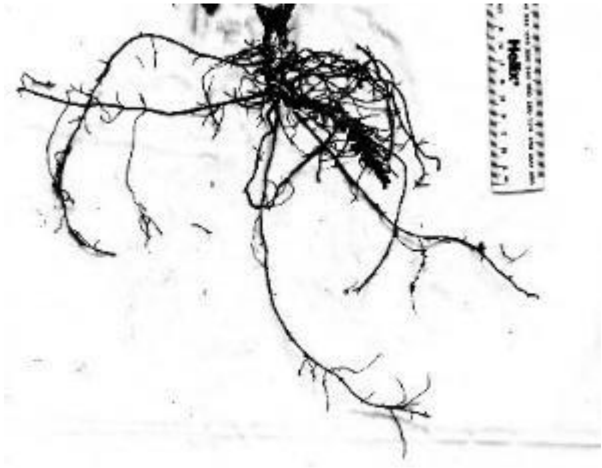
Soil profiles – X-ray tomography: Sandy loam

After: Millington et al., 2017. In conjunction with University of Nottingham (Mooney)

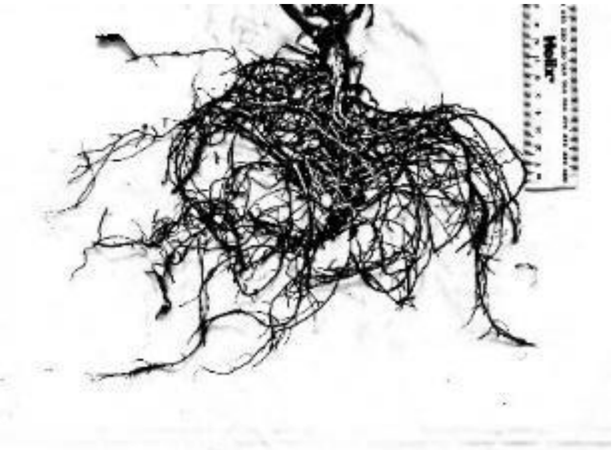


Winter bean root morphology analysis results

STP Shallow



CTF Deep



Kaczorowska - Dolowy, 2022

Effect of tillage and traffic systems on indicators of soil health

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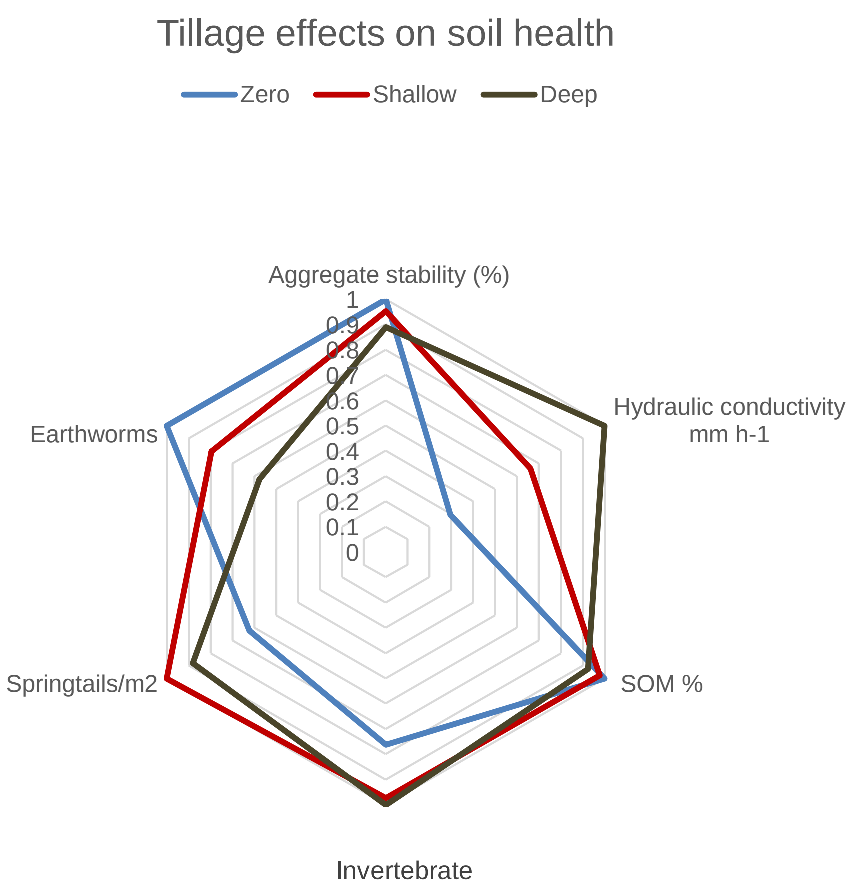
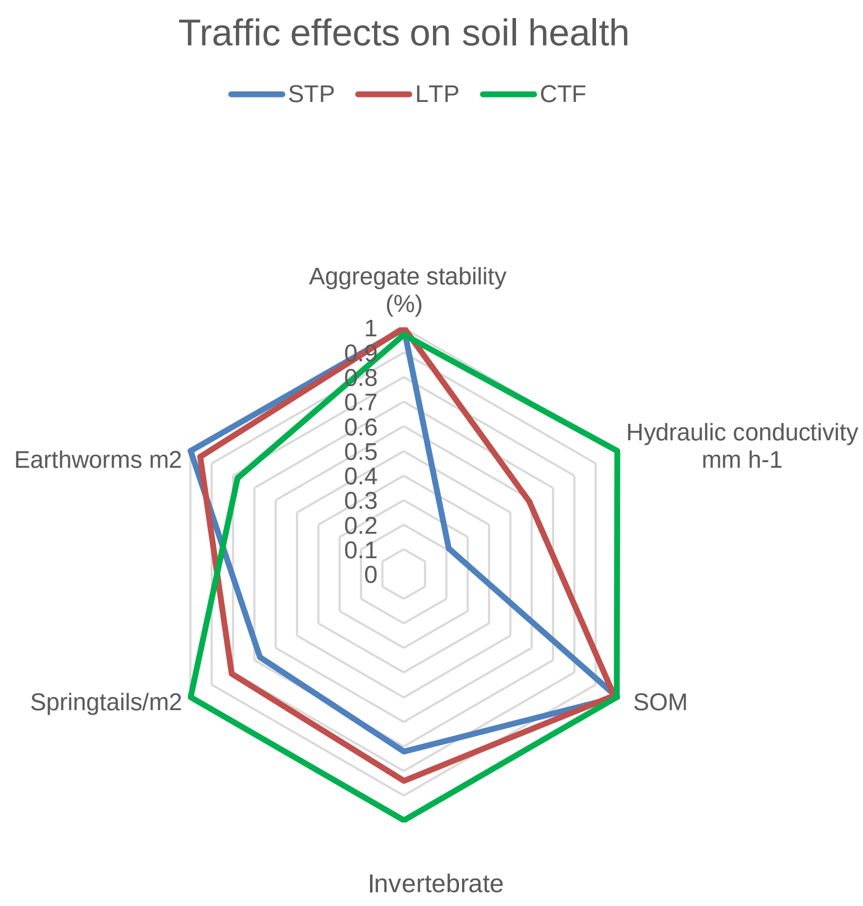


All indicators have significant differences



Aggregate stability, Soil organic matter & Earthworms
Are not statistically different

After: Kaczorowska-Dolowy et al. 2020

Preliminary results on SOC

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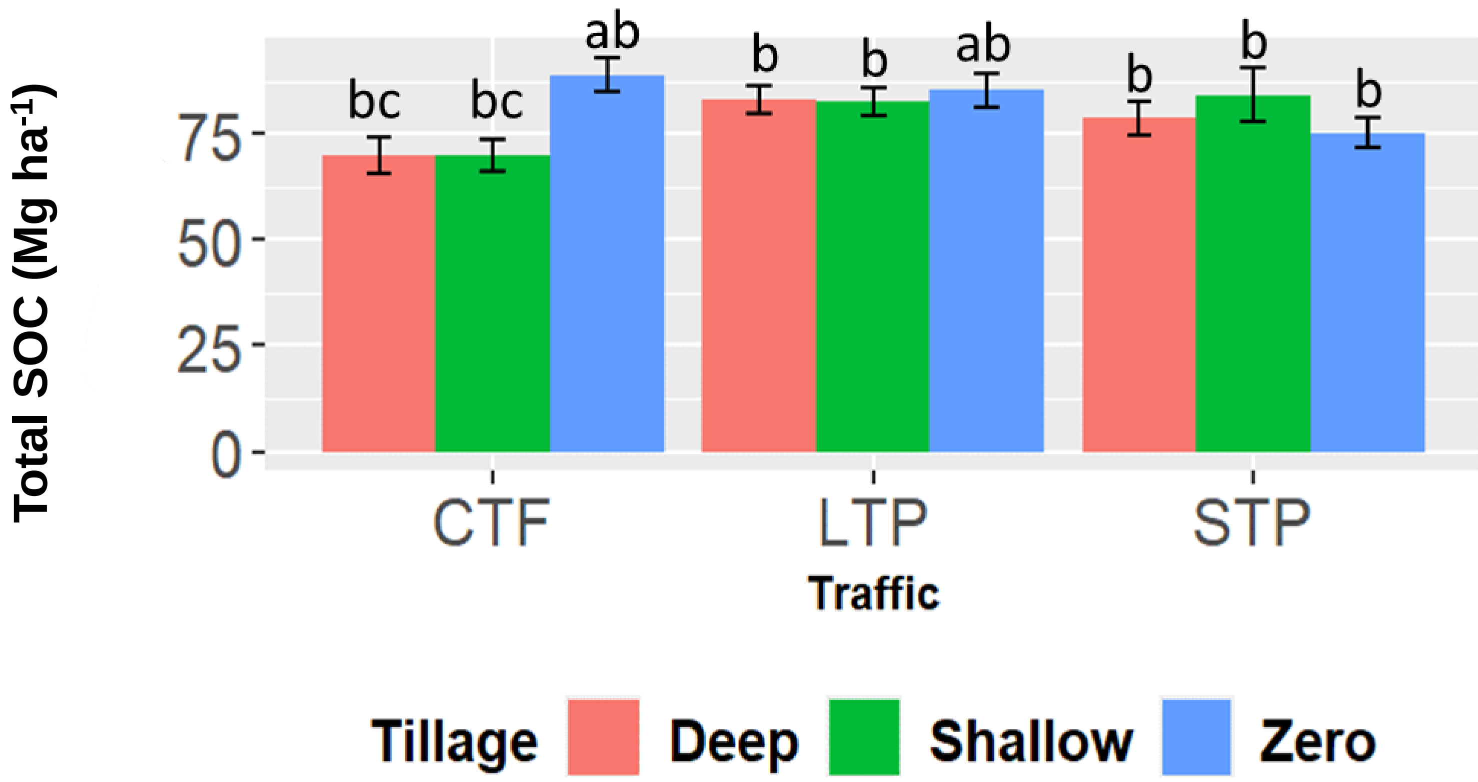
Crop: winter barley

Sample date: 17th August 2021



Zero-tilled soil stored about 5 Mg/ha of SOC more than either the shallow or deep tilled soil.

Tillage vs. Traffic Study

Winter Wheat Yield 2013

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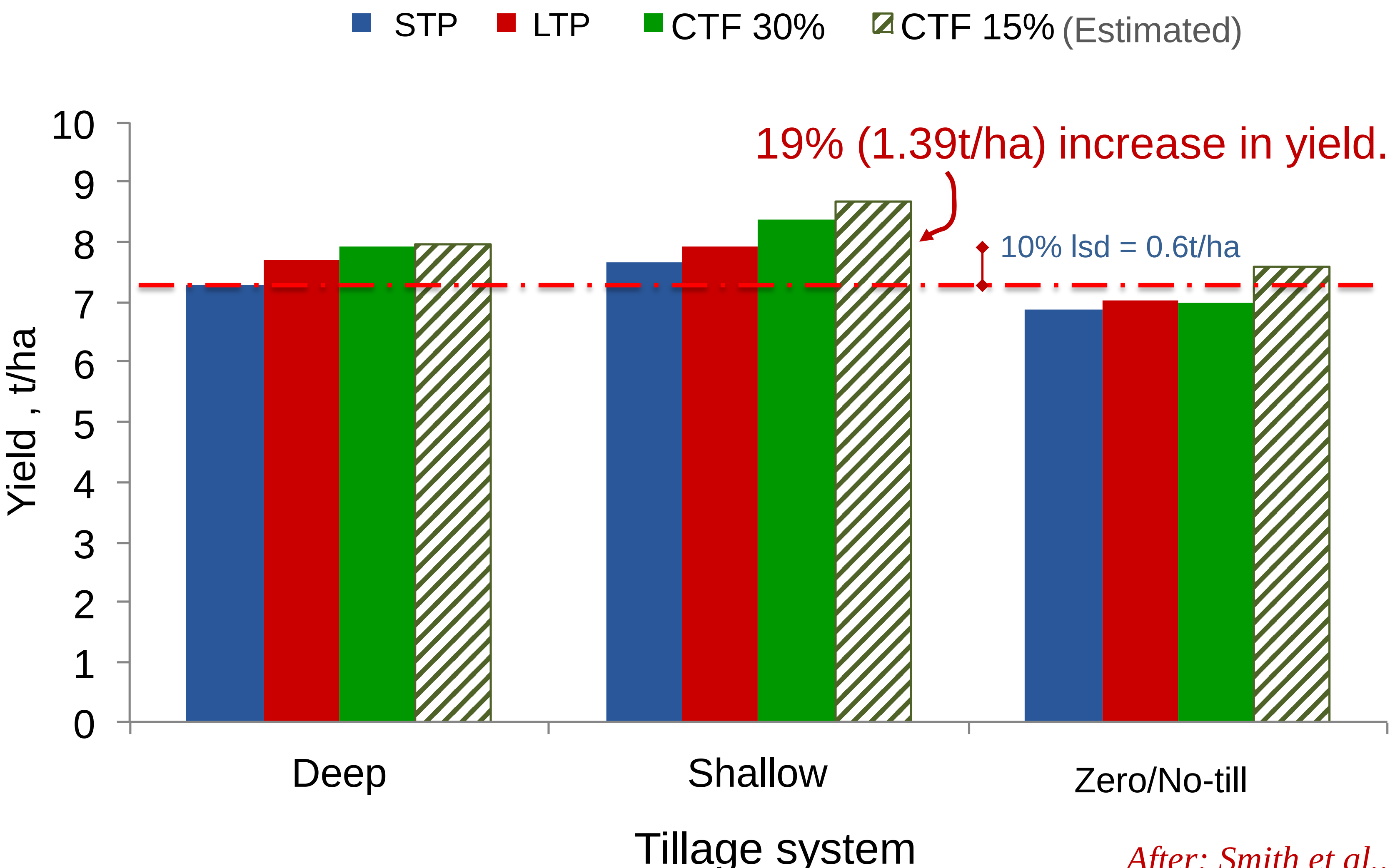
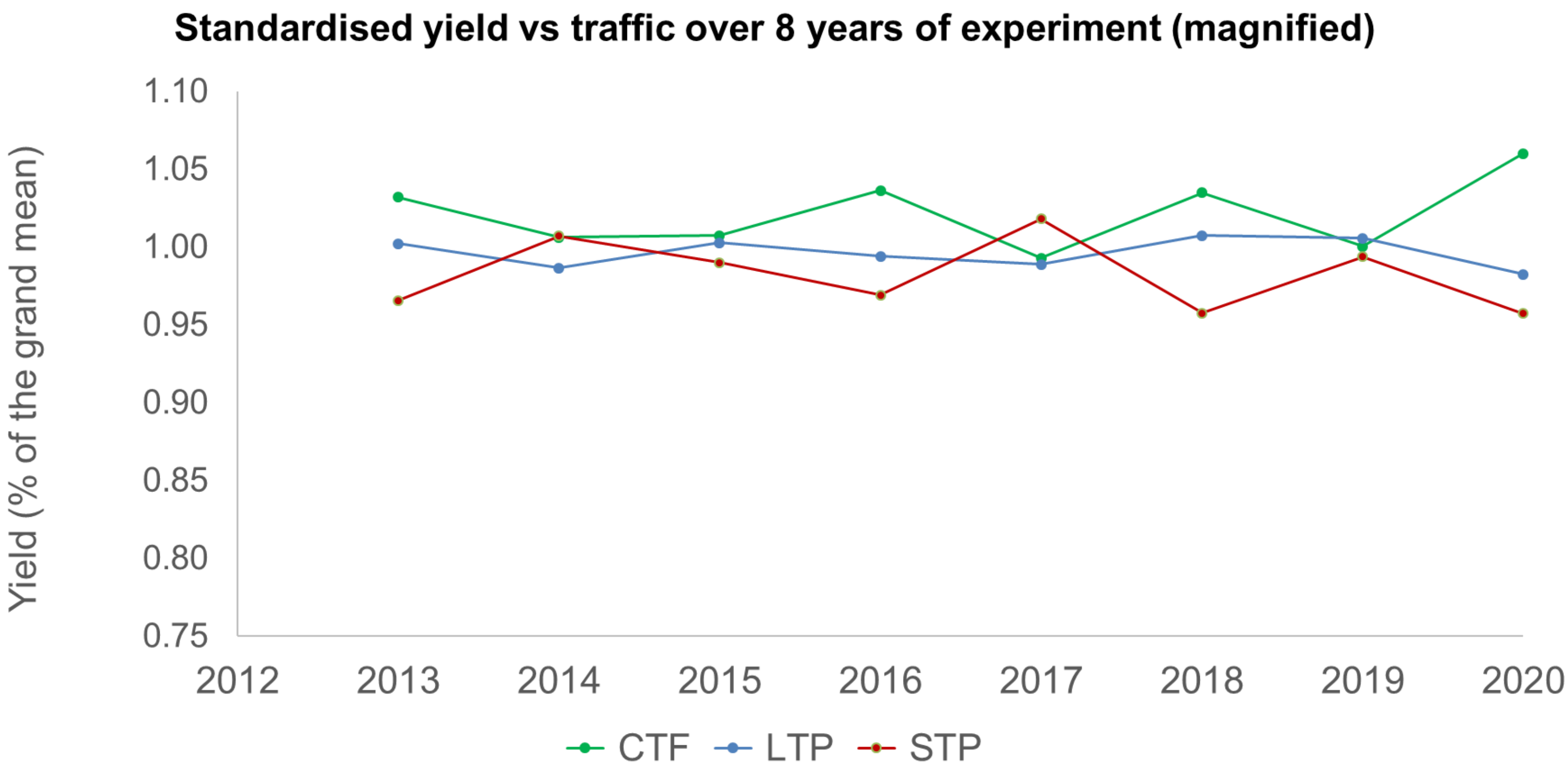


After: Smith et al., 2014

Effects of traffic on the long term crop yields



$CTF_{30\%}$ results in a 4% yield improvement

$CTF_{15\%}$ results in a 7% yield improvement

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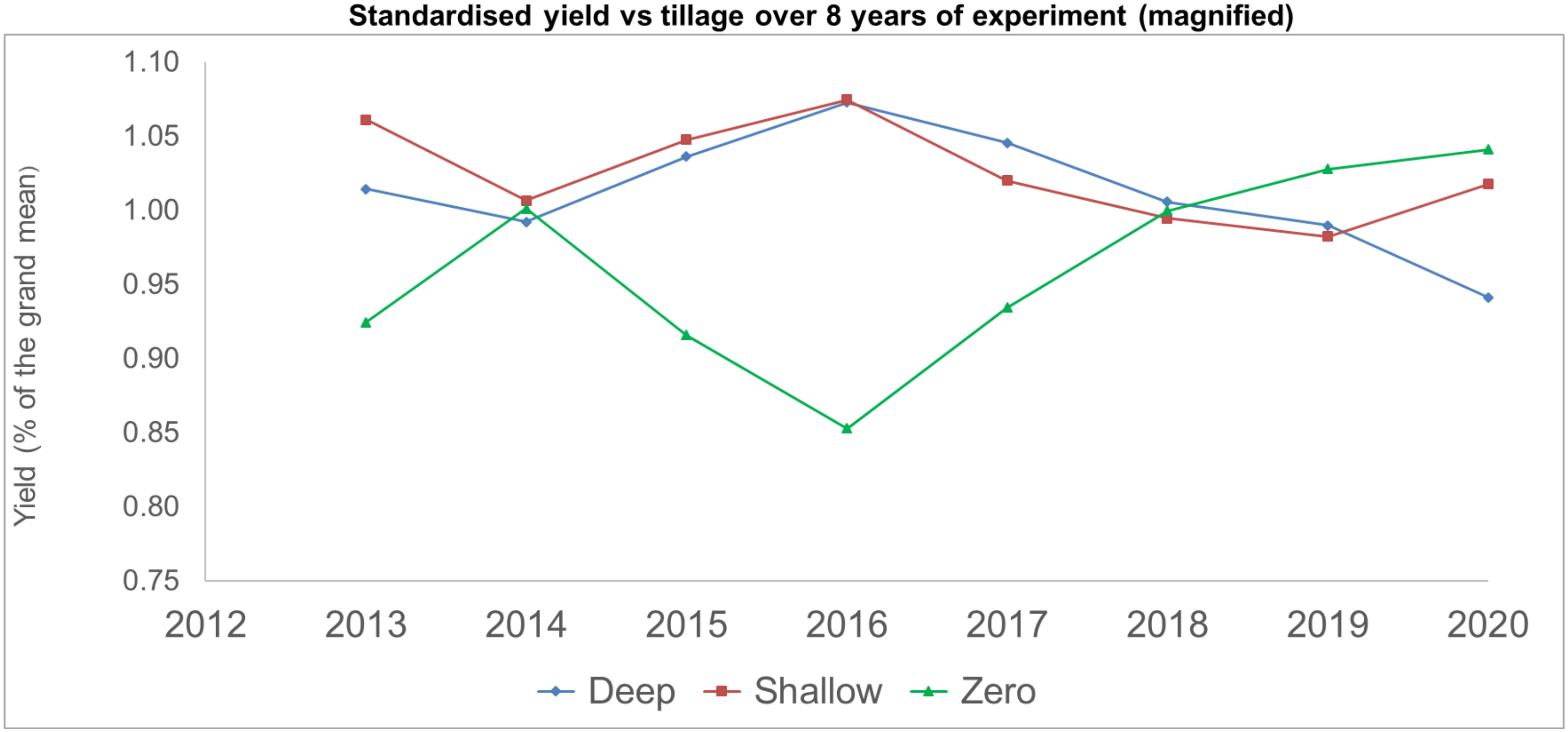
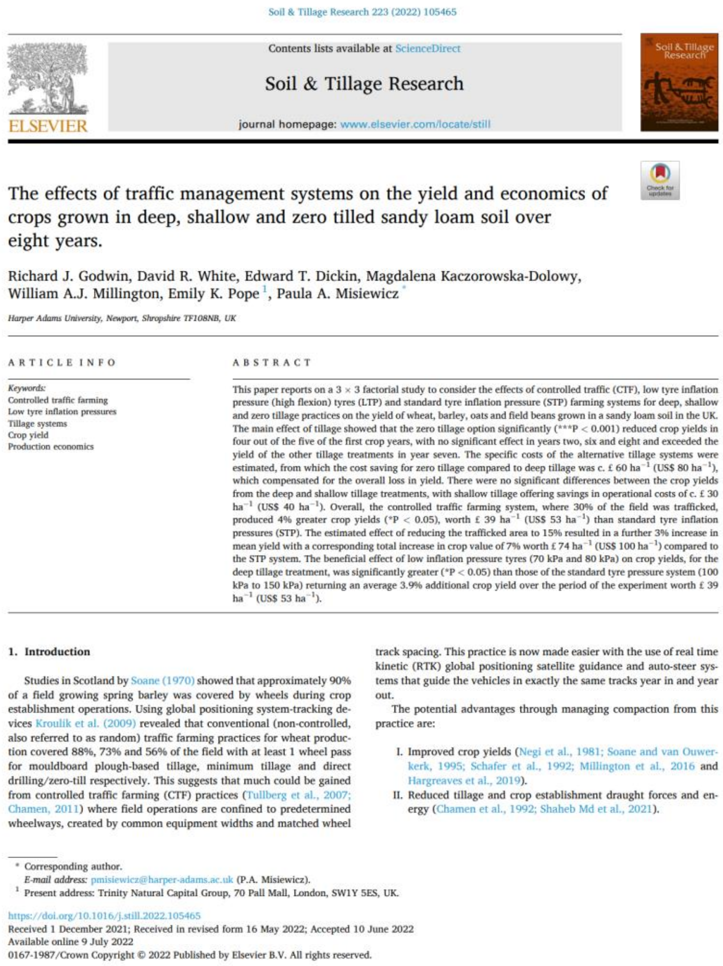
The effect of tillage and time on crop yields



Conclusions: yield

1. Deep tillage gives no yield advantage
2. Shallow tillage gives the best compro structure.
3. Zero tillage produces lower yields ini over time as the soil structure develo
4. The benefits of mitigating traffic (LTP start of the system and are consister
5. Deep tilled soil benefits the most fro indicating that loosening and re-com damage to soils.
6. Zero tilled soils show the least respo indicating that they are more resilier



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The effects of traffic management systems on the yield and economics of crops grown in deep, shallow and zero tilled sandy loam soil over eight years.

Richard J. Godwin, David R. White, Edward T. Dickin, Magdalena Kaczorowska-Dolowy, William A.J. Millington, Emily K. Pope[1], Paula A. Misiewicz*

Harper Adams University, Newport, Shropshire TF108NB, UK

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ABSTRACT

This paper reports on a 3 × 3 factorial study to consider the effects of controlled traffic (CTF), low tyre inflation pressure (high flexion) tyres (LTP) and standard tyre inflation pressure (STP) farming systems for deep, shallow and zero tillage practices on the yield of wheat, barley, oats and field beans grown in a sandy loam soil in the UK. The main effect of tillage showed that the zero tillage option significantly (***$P < 0.001$) reduced crop yields in four out of the five of the first crop years, with no significant effect in years two, six and eight and exceeded the yield of the other tillage treatments in year seven. The specific costs of the alternative tillage systems were estimated, from which the cost saving for zero tillage compared to deep tillage was c. £ 60 ha^{-1} (US$ 80 ha^{-1}), which compensated for the overall loss in yield. There were no significant differences between the crop yields from the deep and shallow tillage treatments, with shallow tillage offering savings in operational costs of c. £ 30 ha^{-1} (US$ 40 ha^{-1}). Overall, the controlled traffic farming system, where 30% of the field was trafficked, produced 4% greater crop yields (*$P < 0.05$), worth £ 39 ha^{-1} (US$ 53 ha^{-1}) than standard tyre inflation pressures (STP). The estimated effect of reducing the trafficked area to 15% resulted in a further 3% increase in mean yield with a corresponding total increase in crop value of 7% worth £ 74 ha^{-1} (US$ 100 ha^{-1}) compared to the STP system. The beneficial effect of low inflation pressure tyres (70 kPa and 80 kPa) on crop yields, for the deep tillage treatment, was significantly greater (*$P < 0.05$) than those of the standard tyre pressure system (100 kPa to 150 kPa) returning an average 3.9% additional crop yield over the period of the experiment worth £ 39 ha^{-1} (US$ 53 ha^{-1}).

1. Introduction

Studies in Scotland by Soane (1970) showed that approximately 90% of a field growing spring barley was covered by wheels during crop establishment operations. Using global positioning system-tracking devices Kroulik et al. (2009) revealed that conventional (non-controlled, also referred to as random) traffic farming practices for wheat production covered 88%, 73% and 56% of the field with at least 1 wheel pass for mouldboard plough-based tillage, minimum tillage and direct drilling/zero-till respectively. This suggests that much could be gained from controlled traffic farming (CTF) practices (Tullberg et al., 2007; Chamen, 2011) where field operations are confined to predetermined wheelways, created by common equipment widths and matched wheel track spacing. This practice is now made easier with the use of real time kinetic (RTK) global positioning satellite guidance and auto-steer systems that guide the vehicles in exactly the same tracks year in and year out.

The potential advantages through managing compaction from this practice are:

I. Improved crop yields (Negi et al., 1981; Soane and van Ouwerkerk, 1995; Schafer et al., 1992; Millington et al., 2016 and Hargreaves et al., 2019).
II. Reduced tillage and crop establishment draught forces and energy (Chamen et al., 1992; Shaheb Md et al., 2021).

* Corresponding author.
E-mail address: pmisiewicz@harper-adams.ac.uk (P.A. Misiewicz).
[1] Present address: Trinity Natural Capital Group, 70 Pall Mall, London, SW1Y 5ES, UK.

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Tyre inflation pressure study

Champaign - Urbana, Illinois

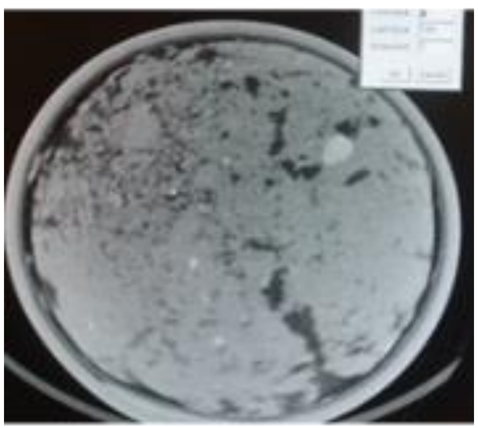
Silty clay loam
Corn and Soybean

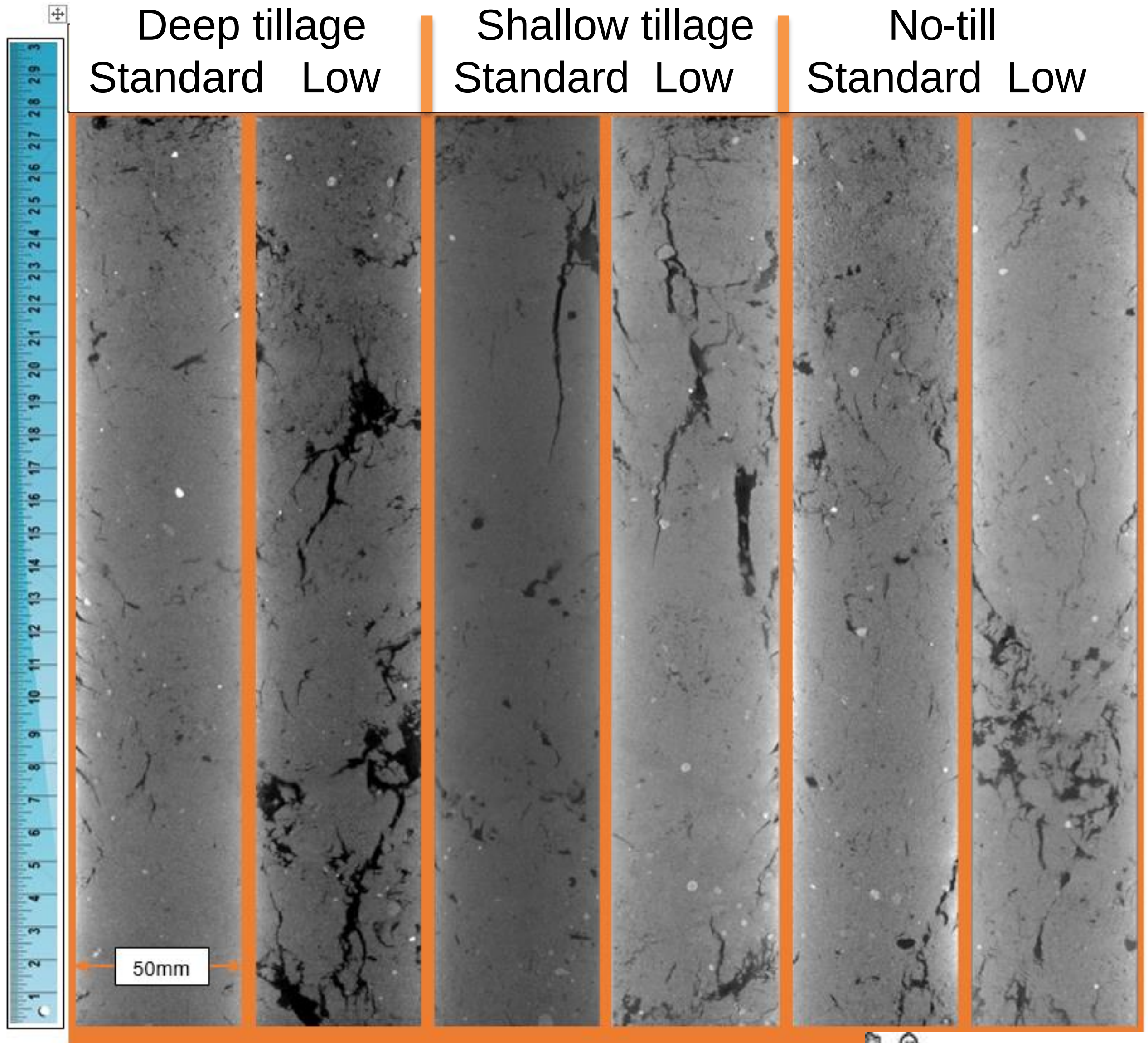
Design:
2 x 3 Factorial Design-Randomised Complete Block

2 Tyre pressures	3 Tillage systems
Standard pressure (STP): 1.4bar – tillage 1.2bar – planting 2.1bar – harvest	Deep tillage (DT): 450mm
	Shallow tillage (ST): 100mm
	No till (NT)
Low pressure (LTP): 0.7bar – tillage 0.5bar – planting 1.4bar – harvest	Deep tillage (DT): 450mm
	Shallow tillage (ST): 100mm
	No till (NT)

After: Shaheb et al. 2019

Soil profiles - X-ray tomography: Silty Clay Loam





After: Shaheb et al. 2019 in conjunction with the Beckman Institute of Advanced Science and Technology, University of Illinois

Effect of traffic and tillage systems on crop yield

LTP had a 4.3% Significant increase in Corn yield in 2017

LTP had a 2.8% Significant increase in Corn yield in 2018

LTP had a 0.6% Non- Significant decrease in Soybean yield in 2017

LTP had a 3.7% Significant increase in Soybean yield in 2018

After: Md Rayhan Shaheb 2019

Hands Free Hectare

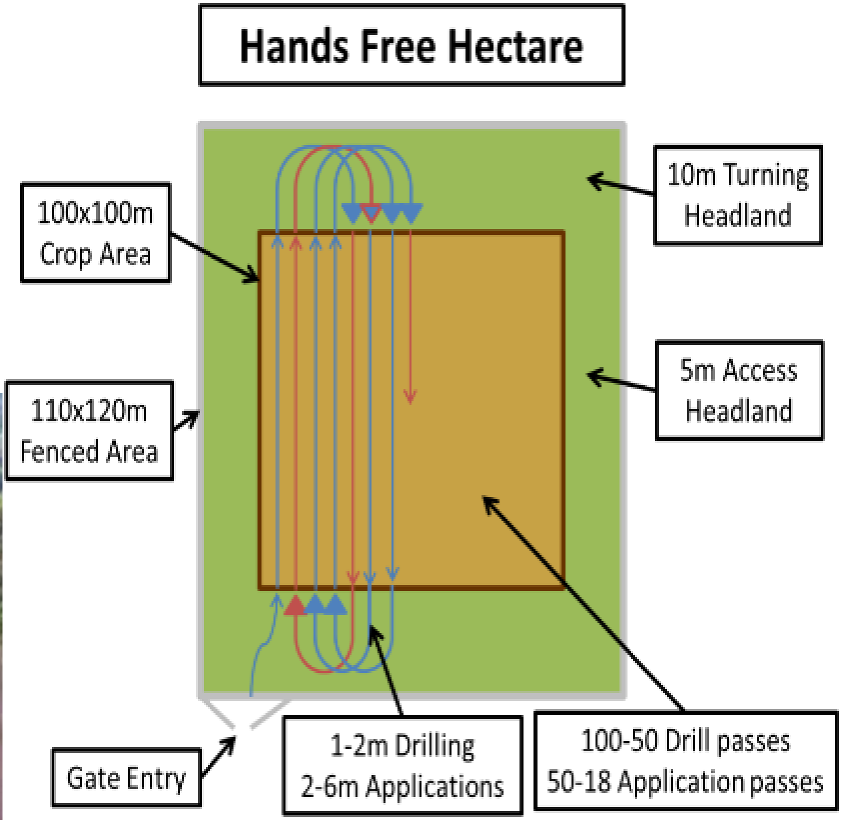
www.handsfreehectare

National Centre for Precision Farming

Harper Adams University

Automated machines growing the first arable crop remotely, without operators in the driving seats or agronomists on the ground.

- Commercial compact farm machinery
- "Open source" automation



Precision Decisions

Autonomous low mass vehicles
(Hands Free Hectare & Farm)

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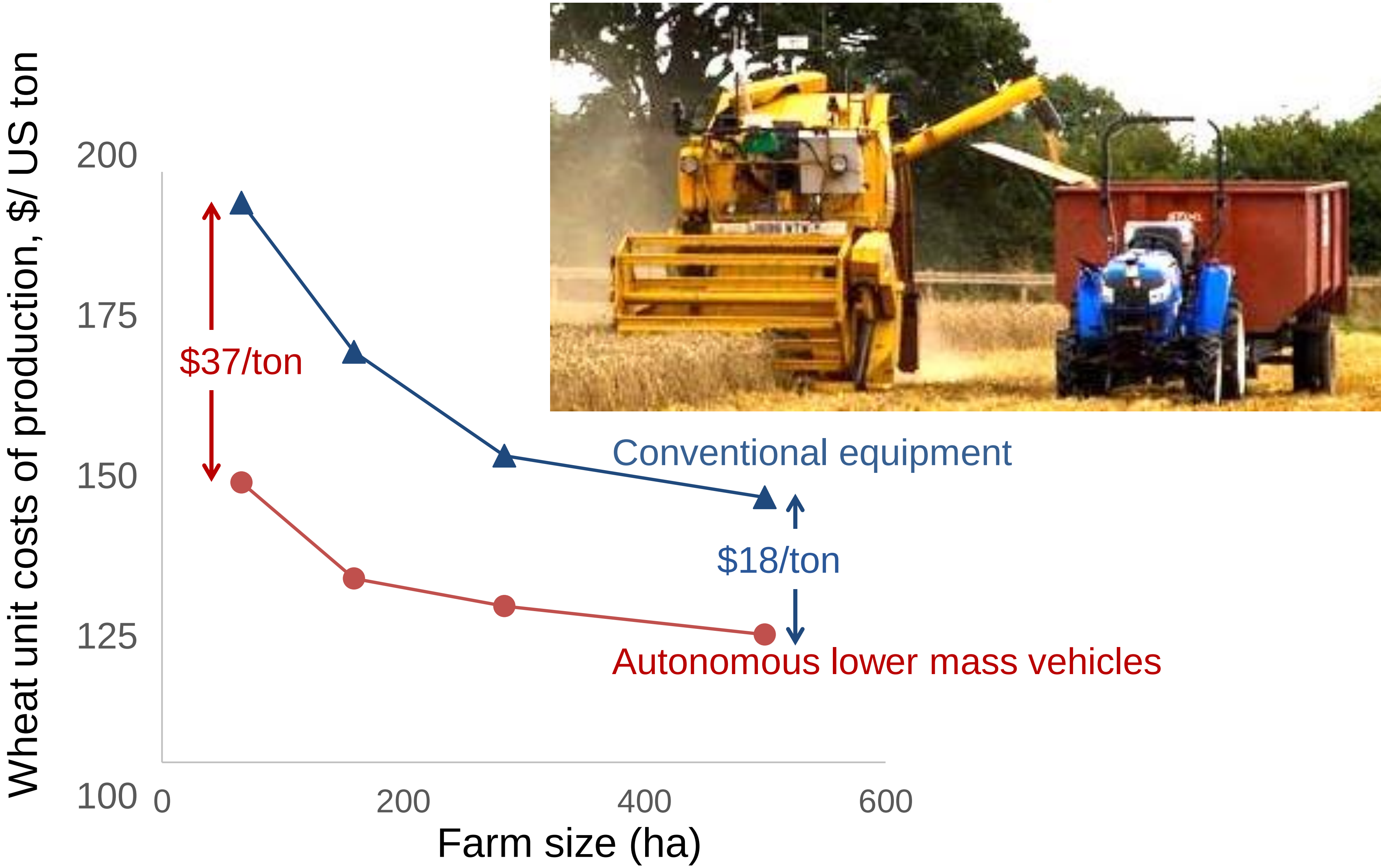
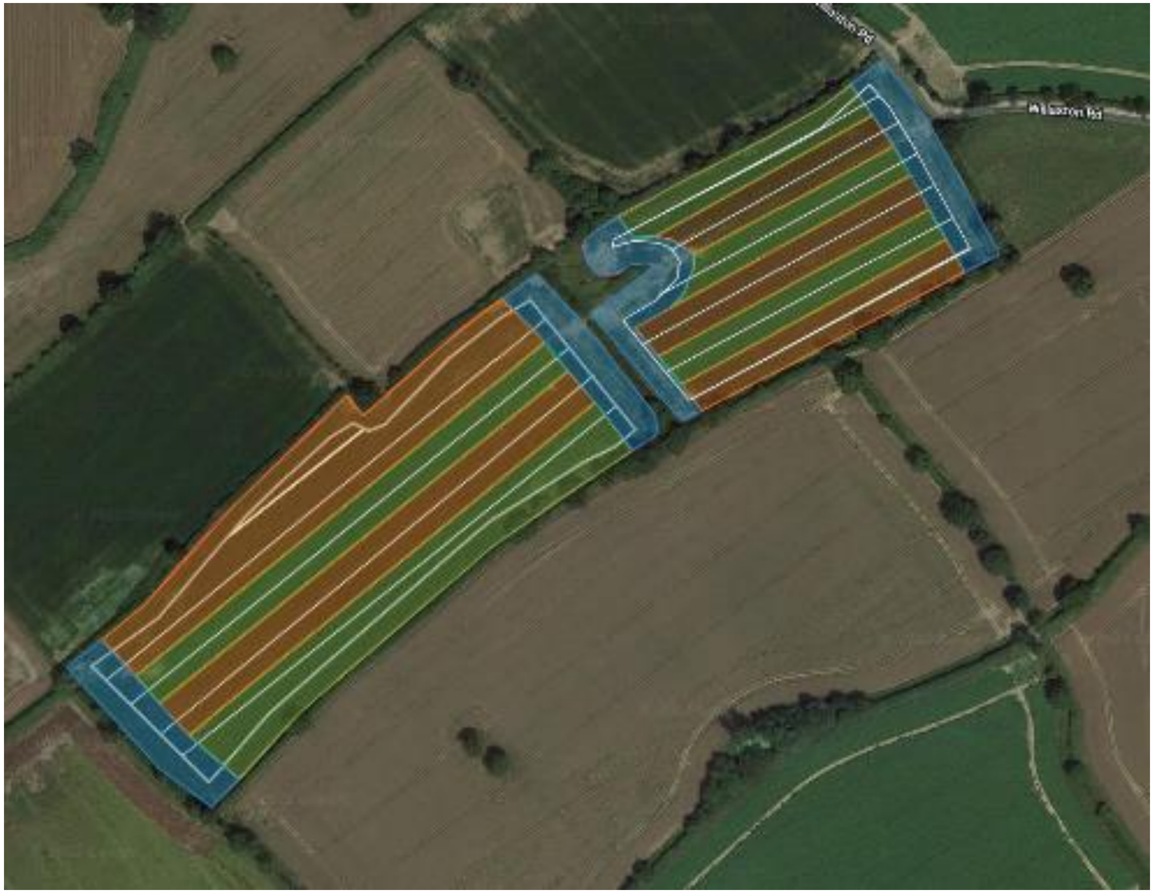


Lowenberg-DeBoer, Behrends, Godwin and Franklin, 2019

Beyond research to impact: BSI Crop Robot Code of Practice guidance on:

- Human supervision requirements under different circumstances (e.g. on-site vs remote)?
- Field speed and robot size under different circumstances?
- Training required for human supervisors of crop robots?
- Site preparation for crop robot use (e.g. signage, fencing, alerting neighbours)?
- Reporting human-robot incidents?
- Managing robots for environmental protection and avoiding ecosystem damage?
- Preventing theft of robots?

Regenerative Agriculture: System's Level Investigation



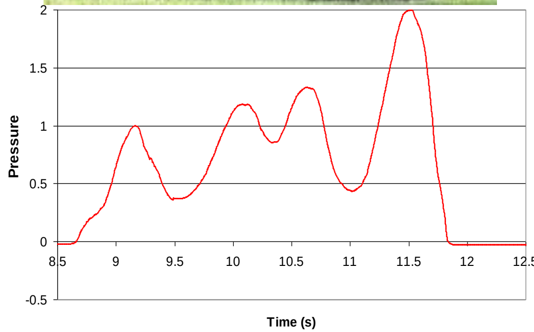
Source: Jeffery (2022)

Concluding remarks

- Compaction
  - Can reduce yields by 10-15%
  - Increases tillage energy, time and costs
  - Reduces infiltration and hence increases runoff and flooding
- Improved soil security and farming system's resilience can be achieved by
  - Fitting lower inflation pressure tyres / tracks
  - Controlled Traffic Farming (CTF) systems
  - Zero tillage
  - Reduction and redistribution of vehicle mass
- Agronomic benefits
  - CTF increased the crop yield between 4 – 7%
  - LTP has the potential to increase crop yield up to 4%
- Future alternative vehicle systems are under investigation

Future developments

- Soil displacement/failure modeling
- Whole tillage machine soil disturbance prediction i.e. feed in the soil disturbance required and let the system identify the optimum tillage configuration
- Re-examine the potential of improved track systems
- Alternative vehicle systems
- Soil health, carbon and emissions
- Biophysical modelling to allow extrapolation of results to other situations within the UK to guide adoption, practice change and future experimentation.



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- My many colleagues, doctoral students and associates