River Wensum DTC

Research Update 2

DIRECT DRILLED FIELD, SALLE PARK ESTATE, NORFOLK

MARCH 2019

Reduced tillage trials aim to improve soil sustainability

The Salle Park Estate, Norfolk, has hosted a five year (2013–2018) reduced cultivation trial to assess the impact of contrasting tillage regimes on the biological, chemical and physical condition of soils.

The main objective of reduced, non-inversion tillage systems is to improve soil structure and stability. In conventional tillage systems, the soil is typically inverted to a depth of >20 cm using a mouldboard plough prior to secondary cultivation to create a seedbed into which the subsequent cash crop is sown. However, under non-inversion tillage systems the soil is either disturbed to a lesser degree (i.e. shallow non-inversion tillage to a depth of <10 cm using discs or tines) or not disturbed at all, with sowing occurring directly into the residue of the previous crop (i.e. direct drilling).

By improving soil structure, non-inversion tillage methods have previously been shown to reduce soil erosion, increase organic matter content, improve drainage and water holding capacity and increase microbial and earthworm activity. However, the lack of inversion has also previously been reported to increase pest populations and lead to an accumulation of nutrients near the soil surface which can be readily mobilised by surface flows and thus pose a risk to freshwater environments.

Working across nine fields covering 143 ha of arable land **(Figure 1)**, three contrasting tillage regimes were established:

- **Block J:** conventional mouldboard ploughing to 25 cm depth;
- **Block P:** shallow non-inversion to 10 cm depth using the disks and tines of a Väderstad *Topdown* and *Carrier*;
- **Block L:** direct drilling with zero inversion using a Väderstad *Seed Hawk* direct drill.

All three of the blocks were in a rotation of spring bean (2013/14), winter wheat (2014/15), winter barley (2015/16), oilseed rape (2016/17) and winter wheat (2017/18). To minimise the risk of background variability in soil conditions and historic cultivation practices masking the impacts of the trial, each block contained the same range of soil textures and historically had been subjected to the same seven-year crop rotation, meaning that all blocks would have had comparable fertiliser inputs. The impact of the tillage regimes was assessed by regular

DEMONSTRATION TEST CATCHMENTS

The Demonstration Test Catchments (DTCs) are a £12.3 m research platform established by DEFRA in 2010 to investigate the extent to which on-farm mitigation measures can cost-effectively reduce the impact of diffuse water pollution on river ecology whilst maintaining food production capacity.

Four DTCs were established across the UK to provide an evidence base for farming in contrasting agricultural systems. These were:

- River Wensum, Norfolk (arable)
- River Eden, Cumbria (upland)
- River Avon, Hampshire (mixed dairy)
- River Tamar, Devon (livestock)

FURTHER DETAILS:
http://www.wensumalliance.org.uk/

FAST FACTS

16-26%

Increase in soil organic carbon across all tillage regimes

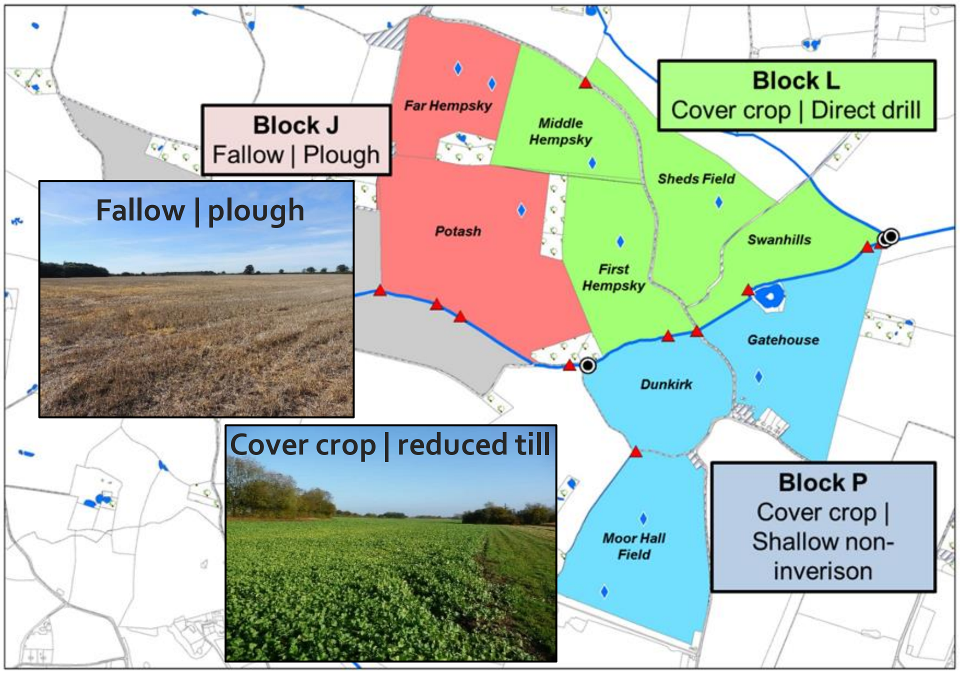

Figure 1: Location of the Salle Park Estate reduced tillage trial (2013-2018), with weekly drain sampling sites (red triangles), porous pot locations (blue diamonds) and bankside monitoring kiosks (black circles) highlighted.

monitoring of four locations within each field (i.e. 4 locations x 9 fields = 36 sites in total) of soil texture, soil structure, infiltration rate, bulk density, soil mineral nitrogen, available phosphorus, available potassium, available magnesium, organic matter content, soil respiration rates and earth worm population counts. The results of this monitoring are shown in **Figures 2** to **6**.

Bulk density

Soil bulk density **(Figure 2)** is an indicator of soil compaction, with higher bulk density values typically indicating a more compacted soil which can restrict root penetration and thereby inhibit crop growth. In this trial, average bulk density values can be seen to follow a consistent trend with peaks and troughs broadly replicated across all three blocks. Bulk density values are consistently the lowest on the ploughed block and highest on the direct drill, which could be an indicator of increase soil compaction under the reduced tillage regime – an effect that has previously been reported in the scientific literature. However, it should be noted that bulk density was highest in Block L and lowest in Block J before the trials commenced in September 2013 and thus this pattern is more likely to reflect differences in soil texture across the blocks (clay loam in Block J, sandy loam in Block L) than impacts of the contrasting tillage regimes. **Overall, it can be concluded that reduced tillage has not significantly impacted upon the soil bulk density.**

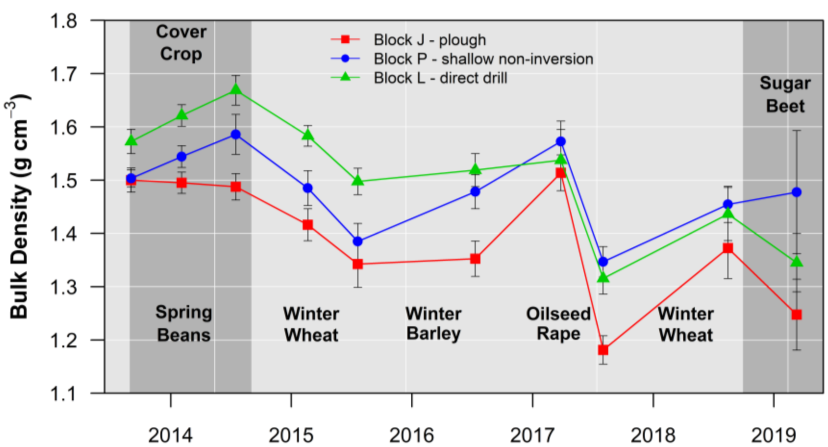

Figure 2: Average soil bulk density values (0-15 cm depth) recorded across the three trial blocks between September 2013 and March 2019. Dark grey shading indicates the period of the 2013/14 and 2018/19 cover crop trials on these fields.

Organic carbon

Soil organic carbon (SOC) content is an important metric for assessing both the structural stability and fertility of soils. A SOC concentration of 2% is considered to be the threshold below which sustainable long-term functioning of soils cannot be maintained without significant organic and inorganic amendments. Previous research of reduced tillage systems has indicated that SOC contents increase under no-till systems due to both the retention of crop residues on the soil surface and due to the reduced exposure of soil organics to oxygen which thereby restricts respiration and conversion of soil carbon to CO_2.

Here, over the duration of the trial **(Figure 3)**, relative increases in SOC content of 16% under shallow non-inversion, 22% under direct drill and 26% under plough were observed, with all blocks again following a consistent pattern. SOC content on Block J started and ended the highest which likely reflects the higher clay content of this block. Whilst SOC did increase under direct drill, the fact it also increased under plough suggests this was not related to the tillage method and, **overall, it can be concluded that reduced tillage did not significantly improve soil organic carbon contents.**

Nutrients

Previous research has reported an accumulation of nutrients at the soil surface under reduced tillage regimes due to a lack of soil inversion limiting incorporation of nutrients deeper within the soil profile.

Here, available phosphorus concentrations **(Figure 4)** in the upper 15 cm were elevated under both direct drill and shallow non-inversion relative to plough. However, it appears this pattern reflects the influence of increased nutrients under the cover crop fields rather than the tillage regimes themselves, with the greatest difference between blocks occurring during the cover crop year 2013/14. In subsequent years, differences between the blocks were reduced to the point that by August 2018 there was no significant difference in the mean concentrations of soil available phosphorus. Note, that a near identical pattern was also observed for soil available potassium and magnesium, whilst for soil nitrogen no apparent differentiation between the three

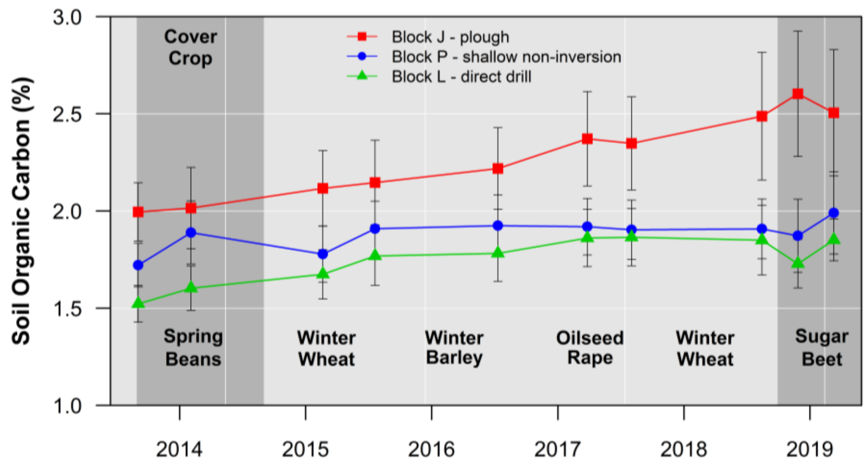

Figure 3: Average soil organic carbon contents (0-15 cm depth) recorded across the three trial blocks between September 2013 and March 2019.

blocks was detected. **Overall, it can be concluded that reduced cultivation has not significantly altered soil nutrient status relative to conventional ploughing.**

Leaching losses

A key aspect of the tillage trials was to assess what impact reduced cultivations had on nutrient leaching losses from arable land into the River Wensum. **Figure 5** shows the concentration of dissolved nitrate recorded in field drain outflows beneath the three trial blocks between February 2013 and April 2017. The greatest distinction between blocks occurs during the cover crop year (2013/14) when nitrate leaching losses were 75% lower under shallow non-inversion with a cover crop and 88% lower under direct drill with a cover crop, than under plough with fallow (see *Wensum DTC Research Update 1*).

During the subsequent four years when only reduced cultivations were trialled (i.e. no cover crops) there was no significant distinction in nitrate leaching losses between blocks. During winter 2014/15 losses were comparable for all blocks; during winter 2015/16 leaching losses were slightly higher under the reduced tillage blocks; during winter 2016/17 this reversed with slightly higher losses under plough; and during winter 2017/18 losses were again higher under reduced tillage. During winter 2018/19, a third winter cover crop trial across these blocks meant that the dramatic differences recorded during this year were a reflection of the cover crop rather than the reduced tillage systems.

Over the four years (2015-2018) since the first cover crop trial, mean nitrate concentrations in field drain outflows were 3.3 mg N/L under plough, 5.4 mg N/L under direct drill and 5.8 mg N/L under shallow non-inversion. All average values were therefore below the EU WFD 11.3 mg N/L standard for safe drinking water. **Therefore, overall it can be concluded that the reduced tillage systems had no significant impact on nutrient leaching losses from arable fields.**

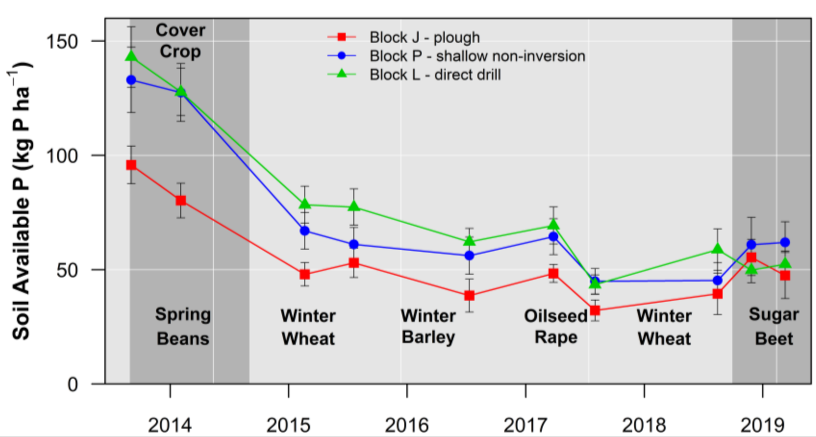

Figure 4: Average soil available phosphorus concentrations (0-15 cm depth) recorded across the three trial blocks between September 2013 and March 2019.

Block J: mouldboard plough

Block P: *TopDown + Carrier*

Block J + P: *Rapid* drill

Block L: *Seed Hawk* direct drill

Soil biology

The impact of contrasting tillage regimes on soil biological health was assessed by measuring earthworm populations on six occasions during the latter half of the trial (April and September 2016; March and September 2017; May and October 2018). Theory suggests that earthworm numbers should be higher under zero-till systems as their habitat (i.e. burrows) is not destroyed by soil inversion and there is more food in the form of crop residues on the soil surface for the worms to consume **(Figure 6)**.

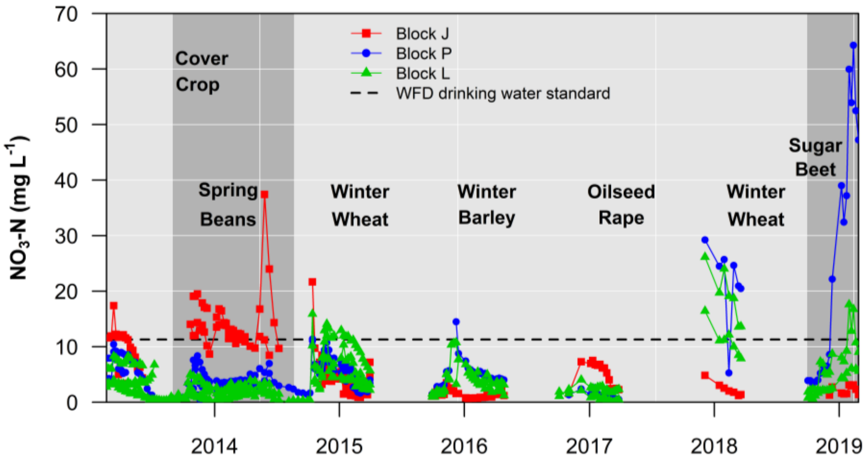

Figure 5: Dissolved nitrate concentrations recorded in field drain outflows beneath the reduced tillage trial area between February 2013 and February 2019.

In contrast to expectations, average earthworm populations were larger under the plough based system in clay loam, sandy loam and sandy silt loam soils than either of the reduced tillage blocks. Only in sandy clay loam soils were earthworm numbers marginally higher under direct drill. Overall, there were an average of 19.4 worms per 0.02 m^3 under plough, 15.9 worms per 0.02 m^3 under direct drill and 13.8 worms per 0.02 m^3 under shallow non-inversion. **It can therefore be concluded that reduced cultivations did not improve earthworm populations.**

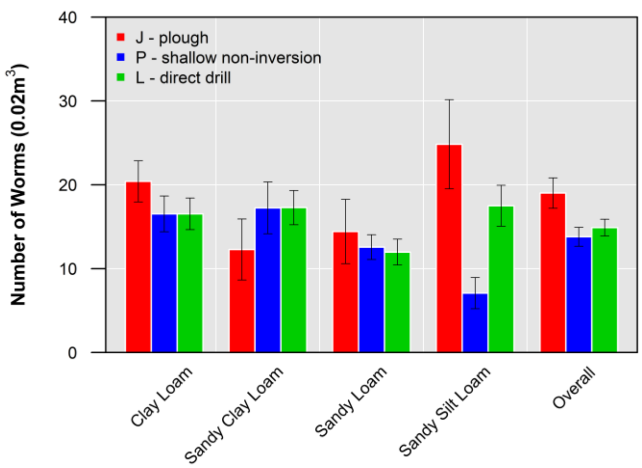

Figure 6: Average earthworm populations recorded under different soil types and cultivation blocks between April 2016 and March 2019.

Economics

The economic performance of the reduced tillage trial is presented in **Table 1**. Previous research has indicated that lower operational costs (e.g. fuel and labour) of non-inversion tillage systems could increase farm margins by £10–85 ha^{-1} compared with conventional mouldboard ploughing.

However, here it was found that operational savings in the reduced tillage Blocks P and L were offset by increased costs associated with additional pesticide applications. This was particularly true for the direct drill block where surface crop residues harboured larger slug populations which necessitated increased molluscicide applications. Profit margins under direct drill were further affected by slightly lower yields than achieved under shallow non-inversion. The net result is that total profit margins over the four years were £3,365 ha^{-1} under shallow non-inversion, £3,314 ha^{-1} under plough and £3,114 ha^{-1} under direct drill.

Therefore, it can be concluded that shallow non-inversion yielded comparable economic performance to the plough based systems, whilst direct drilling resulted in a small (6%) decline in profits relative to conventional practice.

Table 1: Summary of the economic performance of the reduced tillage trial 2013 to 2017.

Block	Unit	2013/14 Spring beans	2014/15 Winter wheat	2015/16 Winter barley	2016/17 Oilseed rape
Block J: plough	Total cost (£ ha^{-1})	589	784	561	600
	Output (£ ha^{-1})	1,334	1,694	1,086	1,734
	Margin (£ ha^{-1})	**745**	**910**	**525**	**1,134**
Block P: shallow non-inversion	Total cost (£ ha^{-1})	748	782	581	553
	Output (£ ha^{-1})	1,506	1,695	1,099	1,729
	Margin (£ ha^{-1})	**758**	**913**	**518**	**1,176**
Block L: direct drill	Total cost (£ ha^{-1})	704	788	598	550
	Output (£ ha^{-1})	1,435	1,620	1,086	1,613
	Margin (£ ha^{-1})	**731**	**832**	**488**	**1,063**

FOR MORE INFORMATION

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FAST FACTS

8%

Increase in profit margin under shallow non-inversion relative to direct drilling