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Crop Production in Southern Britain: Precision Decisions for Profitable Cropping

Platforms to test and demonstrate sustainable soil management: integration of major UK field experiments

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Abstract

Studies on soil tillage and the associated impacts on crop productivity and soil quality have generally been performed on single sites and frequently over a limited number of seasons; this means sites have had insufficient time to develop and restricts the value of comparisons and conclusions. We overcome this in an AHDB/HGCA funded project that studies the oldest established contemporary UK tillage experiments, with all sites sharing ploughed and shallow non-inversion tillage treatments. The sites provide a range of geographic locations and soil types and are located at Mid-Pilmore and the Centre of Sustainable Cropping (Perthshire, Scotland), STAR (Suffolk) and New Farm Systems (Norfolk); established in 2003, 2005 and 2007 respectively. Soil physical conditions and other production characteristics are being assessed under contrasting tillage regimes. Crop yields and farm gate economics are also measured. Early soil assessment data have identified pans under shallow non-inversion tillage that will limit root growth at all sites. Aggregate stabilities also vary, with plough soils at shallow depth being less stable than non-inversion tillage, but greater stability in plough soils at greater depth due to incorporated organic matter. Ongoing research is also examining soil structure temporal dynamics in greater detail, including seedbed resilience to structural degradation through weathering and the action of plants. Analysis of long term yield data from the sites is also being undertaken and is the primary focus of this paper. This is revealing system differences; with ploughing tending to produce the highest mean wheat yields but typically the highest margins have been associated with deep non-inversion tillage systems.

Key words: Soil, tillage, sustainable, management, integration, plough, non-inversion

Introduction

Studies on soil tillage and the associated impacts on crop productivity and soil quality have generally been performed on single sites and frequently over a limited number of seasons; this means sites have had insufficient time to develop and restricts the value of comparisons and conclusions. In contrast the HGCA ‘Soil Platforms’ project (Platforms to test and demonstrate sustainable soil management: integration of major UK field experiments, Project 3786) works in conjunction with the three oldest established contemporary UK tillage experiments. These sites provide a range of geographic locations and soil types. Soil physical conditions and other production characteristics are being assessed under contrasting tillage regimes at sowing, spring growth and post-harvest, with samples being taken to depth in the rooting zone. Crop yields and farm gate economics are also measured. Analysis of long term yield data from the sites is the primary focus of this paper. Key initial findings pertaining to soil management are also presented. The research programme remains ongoing.

Materials and Methods

The four sites utilised within the 'Soil Platforms' project are located at Mid Pilmore (Perthshire, Scotland, established 2003), the Centre of Sustainable Cropping (Perthshire, Scotland, established in 2011), STAR (Suffolk, established 2005) and New Farm Systems (NFS) (Norfolk, established 2007) and each site features contemporary tillage and production regimes. The field experiment sites use fully replicated randomised plot designs on large plots and share ploughed and shallow non-inversion tillage treatments; further details on each individual study are detailed in the following; Mid Pilmore (Newton *et al*., 2012), STAR (Stobart & Morris, 2011) and NFS (Stobart & Morris, 2014). Findings presented in this paper will refer primarily to data collected in the STAR project (Table 1) and the NFS 'cultivations' study (Table 2).

Results

STAR project

Winter wheat yield data from harvest years 2, 4, 6 and 8 of the STAR project are presented in Table 3; this shows the mean data for 'all rotations' and for the 'winter and spring' rotations only (the 'winter and spring' rotations are the most representative of current commercial practice, whereas continuous wheat and alternate fallow would be less common). The full data set is detailed further in Morris *et al*., 2014. Yield differences presented in Table 3 are significant in two of the four seasons and have *P* values of around 0.1 in the other two seasons.

NFS (Cultivations)

Winter wheat yield from harvest years 1, 3 and 5 of the NFS Cultivations Project is presented in Table 4. This shows the mean data for the 'with and without' cover crop rotational approaches. The full data set is detailed further in Morris *et al*. (2014). Yield differences presented for individual seasons are not statistically significant, although P values of around 0.1 in two of the three seasons have been associated with situations where shallow tillage had yields that were notably lower than plough-based approaches.

Discussion

Analysis of soil samples and data interpretation from this project remain ongoing. However, Hallett *et al*. (2014*a;* 2014*b*) have, based on early data, identified at all sites pans under shallow non-inversion tillage that will limit root growth. In addition, aggregate stability has been shown to vary with system, with plough soils at shallow depth being less stable than non-inversion tillage. However, greater stability is evident in plough soils at greater depth due to incorporated organic matter. Findings have indicated that, very rapidly following cultivation, seedbeds coalesce resulting in a more challenging physical environment for crop growth. Current ongoing soil assessment

Table 1. *An outline of the rotation and cultivation treatments in the STAR project in Suffolk (on a Hanslope / Beccles clay soil). Each rotation is repeated with each cultivation approach giving a total of 16 treatments by three replicates*

Rotation	Cropping							
	2005/06 (Year 1)	2006/07 (Year 2)	2007/08 (Year 3)	20008/09 (Year 4)	2009/10 (Year 5)	2010/11 (Year 6)	2011/12 (Year 7)	2012/13 (Year 8)
Winter cropping:	Winter OSR	Winter wheat	Winter beans	Winter wheat	Winter OSR	Winter wheat	Winter beans	Winter wheat
Spring cropping:	Spring beans	Winter wheat	Spring oats	Winter wheat	Spring beans	Winter wheat	Spring linseed	Winter wheat
Continuous wheat	Winter wheat	Winter wheat	Winter wheat	Winter wheat	Winter wheat	Winter wheat	Winter wheat	Winter wheat
Alternate fallow:	Mustard fallow	Winter wheat	Mustard fallow	Winter wheat	Mustard fallow	Winter wheat	Mustard fallow	Winter wheat
Cultivation								
a) Annual plough	Treatment is ploughed every year							
b) Managed approach	Cultivation regime decided annually, based around soil conditions / assessments, previous cropping, weed burden and local best practice							
c) Shallow tillage	Treatment is cultivated to ≈5–10 cm using a non-inversion technique							
d) Deep tillage	Treatment is cultivated to ≈20–25 cm using a non-inversion technique							

Table 2. *An outline of the rotation and cultivation treatments in the NFS 'cultivations' project in Norfolk (on an Ashley series sandy loam soil); each rotation / cover crop combination is repeated for each cultivation approach giving a total of 8 treatments by 4 replicates*

Rotation	2007/08 (Year 1)	2008/09 (Year 2)	2009/10 (Year 3)	2010/11 (Year 4)	2011/12 (Year 5)	2012/13 (Year 6)
Spring breaks	Winter wheat	Spring oilseed rape	Winter wheat	Spring beans	Winter wheat	Spring barley

Management

1. Current; systems run as standard with regard to fertiliser inputs
2. Cover crops; as '1' but with a fodder/oil radish cover crop autumn sown and destroyed overwinter ahead of spring sown crops

Cultivation

a) Annual plough: Treatment is ploughed every year

b) Shallow tillage: Treatment is cultivated to ≈5–10 cm using a non-inversion technique

c) Deep tillage: Treatment is cultivated to ≈20–25 cm using a non-inversion technique

d) Managed approach: Cultivation regime decided annually, based around soil conditions / assessments, previous cropping, weed burden and local best practice.

Table 3. *Mean winter wheat yield data (t ha^{-1}) for winter and spring rotations only (W&S) or all rotations (All) in STAR from years 2 (2006/07), 4 (2008/09), 6 (2010/11) and 8 (2012/13) expressed as t ha^{-1} and as a % of ploughed yields*

	Year 2		Year 4		Year 6		Year 8		Mean	
	W&S	All	W&S	All	W&S	All	W&S	All	W&S	All
Mean yield (t ha^{-1})										
Plough	9.74	8.64	9.44	8.51	7.37	6.83	9.22	8.61	8.94	8.15
Managed	8.91	8.05	9.79	8.83	7.24	6.83	9.21	8.62	8.79	8.08
Shallow	8.49	7.52	9.96	8.80	7.34	7.32	8.77	8.01	8.64	7.91
Deep	9.14	7.78	10.19	9.00	7.80	7.40	8.91	8.30	9.01	8.12
LSD		0.45 (P=0.0001)		0.42 (NS, P=0.14)		0.49 (P<0.05)		0.57 (NS, P=0.11)		
Yield (% of plough)										
Plough	100	100	100	100	100	100	100	100	100	100
Managed	91	93	104	104	98	100	100	100	98	99
Shallow	87	87	105	103	100	107	95	93	97	98
Deep	94	90	108	106	106	108	97	96	101	100

Table 4. *Yield data for winter wheat cultivation practices (mean of ± cover crop) in NFS in Years 1 (2007/08), 3 (2009/10) and 5 (2011/12) expressed as t ha^{-1} and as a % of ploughed yields*

Mean yield (t ha^{-1})	Year 1	Year 3	Year 5	Mean
Plough	12.75	8.26	10.41	10.47
Managed	12.37	7.70	10.42	10.16
Shallow	12.30	7.42	10.48	10.07
Deep	12.55	8.17	10.54	10.42
LSD	0.30 (NS, P=0.16)	0.77 (NS, P=0.11)	0.21 (NS, P=0.56)	
Yield (% of plough)				
Plough	100	100	100	100
Managed	97	93	100	97
Shallow	96	90	101	96
Deep	98	99	101	99

work within the HGCA 'Soil Platforms' project is examining soil structure temporal dynamics in greater detail, including seedbed resilience to structural degradation through natural weathering and the action of plants. Further detail on the winter wheat yield and financial responses from the long term STAR and NFS data sets are discussed in the following.

STAR project

Findings presented in Table 3 indicate that there is relatively little difference in performance ranking in each season, regardless of whether the impact of tillage strategy on yield is compared across 'all' rotations or just across 'winter and spring' rotations. The trends in yield performance expressed as a % of ploughed yield for shallow and deep non-inversion tillage indicate a yield penalty in the first year that all rotations were cropped with wheat (year 2). However, positive yield responses over the plough were apparent for non-inversion systems in the following two seasons of wheat cropping (years 4 and 6); although this response was not seen in year 8. Knight *et al*. (2012) speculated that such changes could be associated with a yield reduction during the transition from ploughing to non-inversion (as has been reported by some growers), potentially associated with soil parameter changes. Morris *et al*. (2014) suggested that this variation could be a response to season and soil conditions in the STAR project; in particular the yield impact in year 8 may have been associated with poor conditions during autumn 2012 at establishment. However, these scenarios may not be mutually exclusive. With regard to mean yield and cultivation approach for both the 'winter and spring' rotation and 'all' rotation approaches, the shallow cultivation approach had the lowest yields, however, in practice these differences were small irrespective of whether data are presented as a mean of 'all' rotations (range of c. 0.25 t ha^{-1}) or for the 'winter and spring' rotations (range of *c*. 0.3 t ha^{-1}). Mean wheat yield data with regard to rotation (irrespective of cultivation system) over this period is also presented by Morris *et al.* (2014). This indicates that there is relatively little difference in yield between 'winter' (8.82 t ha^{-1}), 'spring' (8.87 t ha^{-1}) and 'fallow' (8.59 t ha^{-1}) rotations, however, a yield loss of *c*. 2.5 t ha^{-1} is apparent with respect to 'continuous wheat' (5.99 t ha^{-1}); the reduced yield potential in the continuous wheat was associated ostensibly with crop population and grass weed issues. Yield data presented in Table 3 from the STAR project can be expressed as margin (£ ha^{-1}) data for winter wheat (based on figures described in Morris *et al.* (2014) using gross output minus direct input and machinery costs from spot prices in the year of production) and is presented in Table 5. With regard to cultivation approach for both the 'winter and spring' rotation and 'all' rotation approaches, the highest margins were associated with the 'deep' cultivation system and the lowest with the 'plough'. In both comparisons, the 'deep' approach resulted in a c. 7% increase in margin compared to ploughing.

NFS (Cultivations)

Similar to the STAR project, yield performance expressed as a % of ploughed yield indicated a yield penalty for shallow and deep non-inversion tillage in the first two years of wheat (years 1 and 3), however yields similar to the plough-based system were achieved in year 5 (the third year of wheat). On average, over the three cropping years of winter wheat, the shallow tillage resulted in a small yield loss of around 4 % compared to plough based approach (the deep non-inversion tillage was within 1 % of the plough). Findings from the use of cover crops within the different cultivation systems are not shown in this paper and further details are provided in Stobart & Morris (2014). Yield data presented in Table 4 from the NFS cultivations project can be expressed as winter wheat margin (£ ha^{-1}) (based on figures described in Morris *et al.* (2014) using gross output minus direct input and machinery costs on spot prices in the year of production) and is presented in Table 6. With regard to cultivation approach, the highest margins were associated with the 'deep' cultivation system and the lowest with the 'plough' based system. On average, the 'deep' approach resulted in a c. 5% increase in margin compared to ploughing.

Farming systems

Regarding the findings for both STAR and NFS it should also be noted that non-inversion tillage systems would also typically result in faster working speeds than ploughing; this would also require consideration when interpreting responses to soil management systems and applying them to farm scale (e.g. wider issues associated with timeliness of farm operations). Considering the winter wheat yield data for STAR and the NFS cultivation study, yield differences due to tillage regime in winter wheat were generally small, although there is some indication of slightly lower yield potential with shallow tillage approaches compared to the plough. However, this yield loss is possibly more pronounced on the lighter NFS site (possibly with lighter soils being more prone to loss of structure where some deeper rectification is not applied) and in the earlier years of both projects (potentially some suggestion of soil and system changes over time in favour of non-inversion systems). It should be noted that these findings pertain to winter wheat and do not consider break crops within STAR and NFS rotations. Break crop data in the STAR and NFS projects is more limited, but Morris *et al*. (2014) suggests differences in output due to cultivation / soil management may be greater in break crops. Further information on longer term trends in both cereal and break crop production is needed, in conjunction with a better understanding of links between production potential, systems resilience and soil condition / parameters. The 'Platforms Project' is seeking to identify soil physical indicators for crop productivity that will assist farmers in improving soil management practices for food and environmental security.

Table 5. *Mean margin over input data for winter wheat in STAR for winter and spring rotations only (W&S) or all rotations (All) expressed as £ ha^{-1} (based on spot prices in the year of production) and as a % of ploughed yields*

	Margin (£ ha^{-1})		Margin (% of plough)	
	Mean (W&S)	Mean (all)	Mean (W&S)	Mean (all)
Plough	592	486	100	100
Managed	607	506	103	115
Shallow	595	499	101	106
Deep	633	516	107	107

Table 6. *Mean margin over input data for winter wheat in NFS expressed as £ ha-1 (based on spot prices in the year of production) and as a % of ploughed yields*

	Margin (£ *ha*$^{-1}$)	Margin (% of plough)
Plough	978	100
Managed	992	101
Shallow	988	101
Deep	1023	105

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