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Economic and ecological benefits of reduced tillage in the UK

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Contents

1. Summary

This report reviews the economic benefits that can be achieved from reduced tillage. There are opportunities to maximise yields and gross margins whilst making savings to labour, machinery and fuel costs. Often reduced tillage is used in combination with other pillars of conservation agriculture, a wider rotation and continual soil cover. Increased management is often required by growers, but the benefits can assist in a sustainable arable system, underpinning an Integrated Farm Management (IFM) approach.

Improvements to soil structure by adopting reduced tillage, can also lead to less compaction and erosion, but good drainage is essential on certain soil types to keep seed and root zones free from waterlogging. Benefits of reduced tillage also include improved soil resilience which will help with future climate and weather patterns.

Fewer mechanical intrusions will help with soil biology, but there are nearly as many pitfalls as benefits if careful management is not implemented. The report identifies the challenges surrounding grass weeds, slugs and crop establishment. Healthier soils can help with nutrient recycling but crop residues and nitrous oxide emissions can replace carbon dioxide saved from reduced tractor fuel use. Reducing cultivations also has wider environmental benefits to both farmland biodiversity and ecosystems.

The United Kingdom's agricultural production will need to increase its productivity to compete on a global stage and the economic benefits of reduced tillage could assist in achieving this aim. The reduced tillage benefits, of energy saving and soil protection, may attract financial support in future domestic agricultural policy.

2. Introduction

Cultivations have been used for centuries to prepare soil for planting crops. Traditionally these were carried out with a plough as it helped aerate the soil, incorporate previous crop residues and controlled weeds in readiness for a final seedbed. Such tillage has high energy costs, which can lead to leaching of soil nutrients, reduced soil organic matter and biota, whilst leading to high nitrous oxide emissions (Godwin, 2015).

In the United Kingdom, a series of reduced cultivation methods became popular after stubble burning, but with the subsequent ban a return to ploughing increased to deal with crop residues. As machinery designs advanced, stubble cultivators and drills were adapted to deal with post-harvest straw. The practice of minimal-tillage (known as min-til) began to get more widely adopted with benefits of cost savings, more timely crop establishment and improved farmland ecology (Jones *et al*., 2006). In addition to economic performance, improving soil conditions were the main drivers in a study carried out by (Godwin, 2015).

In this report reduced tillage is compared against a conventional plough based system, highlighting the financial and ecological benefits. Some of the agronomic and environmental challenges of these reduced cultivation systems are highlighted. The table below gives a thorough explanation of reduced tillage practices (Townsend *et al*, 2016), as it is useful be aware of the terminology used when describing cultivation practices.

Table 1 Description of types of tillage practices. NB tillage definitions in the literature vary widely and may differ from those given in this table.

Tillage type	Description
Conventional tillage	Conventional tillage usually relates to ploughing, which involves inversion of the soil with the purpose of loosening the soil and burying weeds and residues from the previous crop. Generally, ploughing is followed by secondary tillage, such as powered or unpowered harrows/discs, although not always such as on lighter soils. [NB Some definitions of conventional tillage include deep noninversion tillage]
Noninversion tillage; reduced cultivation; reduced tillage; minimum tillage	These are tillage practices that do not invert the soil. Some definitions specify maximum cultivation depths (e.g. no greater than 100 mm) and/or a particular percentage cover, usually 30% of crop residues left on the soil surface
Deep reduced tillage	Noninversion tillage to a depth greater than 100 mm/150 mm
Shallow reduced tillage	Noninversion tillage to a depth of less than 100 mm
Strip-tillage	Strips (covering less than a third of the soil surface) are tilled and the residue moved onto the untilled strips. Seeds are then drilled on the tilled strips
Zero-tillage/no-till/direct drilling	This is where the seed is drilled into the stubble of the previous crop with only very minor soil disturbance
Conservation tillage	Reduced tillage combined with at least 30% residue cover, where water erosion predominates, or at least 1120 kg crop residue left on the surface, where wind erosion predominates
Conservation agriculture	Zero-tillage combined with permanent organic soil cover (either residue or cover crop), and diverse crop rotations
Mixed tillage	A farm system that uses both conventional tillage and reduced tillage. This can take the form of rotational ploughing or strategic tillage
Rotational ploughing	A system where the land is ploughed at specific points in the rotation with other tillage practices used in between
Strategic tillage	A flexible, responsive system where ploughing is used within the rotation in response to specific conditions
Secondary tillage	This term tends to refer to shallower and finer-scale tillage practices occurring after the main tillage practice

3. Economics

a. Crop yields

Reduced tillage can give annual yields of combinable crops within 5%, above or below, of those after ploughing. However, there does tend to be greater seasonal variability in yield in reduced tillage regimes (Knight et al., 2012).

In a 2010, national farm business survey by Sutton Bonington, Townsend et al. (2016), data showed 32% of arable land was established under reduced tillage. Wheat yields were as follows with gross margin in brackets;

- Conventional Ploughing - 7.81 tonnes/hectare. (£953)
- Rotational Ploughing – 8.35 tonnes/hectare. (£945)
- Reduced Tillage – 8.29 tonnes/hectare. (£907)

Potential yield-reducing factors highlighted in (HGCA, 2002) include, poor incorporation of crop residues, increase in grass weeds and volunteers and topsoil compaction, especially when associated with poor drainage (AHBD, 2015).

Minimum cultivations can lead to lower production costs, although this does not necessarily mean an increase in margin per hectare if yields are not sustained at previous levels. However, reduced yields need not be accepted as part of a lower-cost establishment system, but an increase in crop management may be required (HGCA, 2002). In a study conducted by The Arable Group (TAG) in wheat crops over four years, the only situation where ploughing gave better yields than minimum tillage, was after the wet autumn of 2000. It not only reduced all yields, in that season, but particularly penalised direct sowing (Knight, 2004).

b. Gross margins

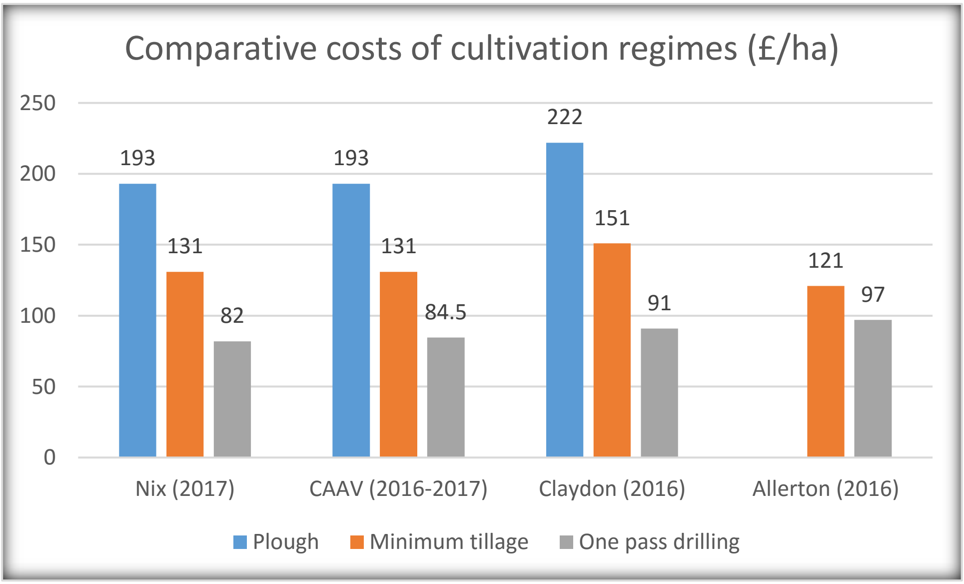
Often growers and their advisors pursue yield without thorough investigation of crop gross and net margin. If increasing yield means a disproportionate increase in variable costs, then margins and profitability can fall. In a reduced tillage regime, the aim is to reduce input costs without sacrificing final yield. The ecological benefits associated with a reduction in tillage can, over time; help with structure, organic matter and nutrient cycling which leads to better soil resilience. These benefits transfer to better financial performance of crop production.

The Townsend *et al*. (2016) report on crop yields showed gross margins that didn't correspond to yields. This was mainly down to increased grass weed control costs (see later). The gross margins of the study are shown below with yields in brackets;

- Conventional Ploughing - £953/hectare. (£953)
- Rotational Ploughing – £945/hectare. (£945)
- Reduced Tillage – £907/hectare. (£907)

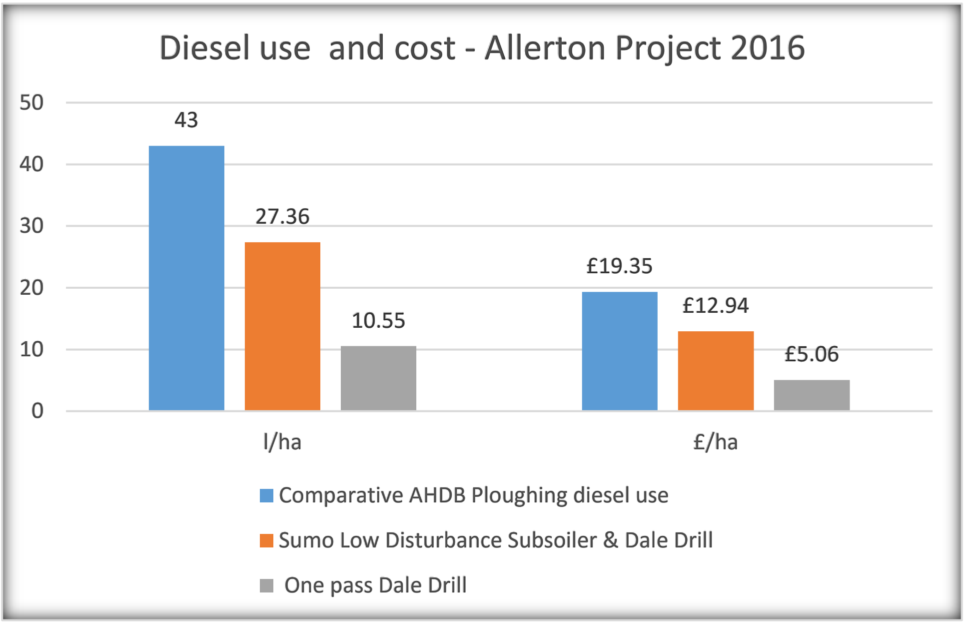
c. Cultivation costs and energy

Reducing cultivations offers real opportunities for farmers to improve profitability (HGCA, 2002). Larger farm units, less labour, larger machines and a move away from traditional plough-based cultivation can deliver in increased savings. The graph below shows cultivation data from several sources (Nix, 2017), (CAAV 2016), (Claydon, 2017) and are compared to those at the Allerton Project. (*The Allerton Project – is a demonstration farm for the Game and Wildlife Conservation Trust, based at Loddington, Leicestershire, United Kingdom).*



*Costs for winter wheat crop, no plough undertaken in 2016 & 2017 at Allerton Project.

The diesel use recorded at the Allerton Project is shown below in litres and £'s per hectare and illustrates the cost savings that can be achieved.



d. Grass weeds

Increased grass weeds are often associated with reduced cultivations, but grass control costs are not always down to the tillage method (HGCA, 1988, 2002, 2012). Poor drainage, increased compaction, tighter rotations and grass weed resistance can all play a part. This is illustrated in the Sutton Bonington report covered earlier (Townsend *et al*, 2016), where grass weed control costs were only £27 lower in the conventional plough system than the reduced tillage system.

Blackgrass has caused numerous problems for growers on heavy clay soils. The effectiveness of most contact grass weed herbicides in large parts of the UK has been severely reduced over the last decade. Residual chemistry is struggling to cope with the huge numbers of seed returned to the soil. Effective application techniques such as increased water volumes, appropriate forward speed (under 12 kmh), improved nozzle technology and boom height are essential components for increased blackgrass control.

In reduced tillage systems blackgrass seeds should be encouraged to germinate from the top few centimetres of soil rather than distributing them evenly through the soil profile. Crop competition, delayed autumn drilling, a wider rotation, spring cropping, fallow, and machinery hygiene can all assist with control. Rotational ploughing may also help as a 'reset button', but machinery set up and the length of years between ploughing are factors to consider.

The wide use of glyphosate, as a broad-spectrum herbicide, is common practice when producing stale seedbeds to control grass weeds. Glyphosate has come under increasing pressure recently, but several studies concluded that it is safe for operators and consumers where used responsibly and at recommended rates. However, there is evidence of increasing levels of glyphosate resistance in both Australia and the USA with "no-till" systems (HGCA, 2012) and a combination of cultural and chemical control approaches should be undertaken.

At the Allerton Project the following correlation between cultivation and grass weed control has been seen since 1999 *(the figures in brackets show are the equivalent 2016 costs).*

Year	Cultivation type	Cultivation Cost £/ha	Grass Weed Control £/ha
1999	Conventional Plough	111 *(177)*	18 *(29)*
2006	Reduced tillage 4 pass	92 *(122)*	50 *(66)*
2016	Reduced tillage 3 pass	97	123

e. Fixed costs -machinery and labour

Reducing costs for both machinery and labour is directly attributable to reduced machinery operations in the field (HGCA 2012). Machinery depreciates at a lower rate with labour costs saved from reduced overtime and casual labour. There may be a further cost reduction, to fixed costs, by downsizing machinery and the sale of surplus equipment.

When looking at net margin and total business profitability, machinery and labour costs should be factored in. Less capital tied up in machinery and lower labour wage bills can compensate for lower crop margins and increase enterprise returns. Farmers must be careful that any reduction in yield is not greater than the saving achieved from reduced cultivations (Leake & Lane, 2009).

f. Management

The full economic benefits of reduced tillage are a combination of factors, the ability of the land managers to use good financial acumen to purchase inputs and market crops is fundamental. The choice and range of cultivation machinery and its effect on fixed costs is often over looked. Machinery that is no longer required should be sold to gain the full advantages of a reduced cultivation system, as it is often the overhead costs that don't get fully addressed. Tom Sewell reported that during his Nuffield scholarship visits he saw farmers whose input costs were less due to reduced fuel, labour and depreciation on machinery. However, his main observation was the financial benefit these farmers gained from the improvement to the farm's main asset, the soil (Sewell, 2014). Successful reduced tillage systems are individually suited to soil type, climate and management expertise, whereas the mouldboard plough is universally applicable (HGCA, 2002).

Reducing tillage achieves increased energy efficiency and conserves seed bed moisture which linked to increased organisation and planning are a part of the principles of Integrated Farm Management (IFM). The IFM 'wheel' highlights the benefits of soil fertility and landscape and nature conservation and reduced tillage has some influence over both these areas.

4. Ecological

a. Soil resilience

In the previous section the economic benefits of reduced tillage were shown to fit into the principles of IFM. Building resilient fertile soil can also be achieved by following ‘Conservation Agriculture’ principles, including minimal soil disturbance, crop rotation and continuous soil cover (Jones et al., 2006). It is becoming increasingly apparent that the UK’s soils will be impacted by more extreme weather patterns. Soil management that builds resilience can help mitigate some of the effects of a changing climate (FAO, 2015), (Payton 2016).

i. Soil structure

Soil structure is a key component for successful arable and livestock enterprises. The functionality of the soil is enhanced if air, water and soil particulates are present in mutually beneficial amounts. In the UK, arable soils tend to have a composition of 25 % air, 25% water, 45% mineral content and 5 % organic matter and this is often highlighted as a balanced soil. The air and water content can vary throughout the year and organic levels can take many years to increase with the right management.

Reducing cultivations can help improve soil structure, but it is important to stress that the timing of operations can have considerable impact. It is often better to delay cultivations and sowing, into the spring, rather than smear and ruin soil structure because of wet conditions. Such damage can be difficult and expensive to rectify. With improved soil structure; crop establishment, rooting and nutrient recycling are all enhanced.

ii. Soil organic matter

Less cultivations during seedbed preparation can lead to reduced mineralisation of organic matter (Webb et al., 2001). Building soil’s organic matter will help with water holding capacity, soil biology and nutrient recycling. Over-cultivation can lead to poorly structured soils that are vulnerable to erosion and can become 'lifeless'. Soil organic matter consisting of fine particles of partially decomposed plant tissue serves as a binding agent to hold soil particles together forming aggregates (Gale et al., 2000). A full report on organic additions appears in the Frank Parkinson Agricultural Trust commissioned report *'The contributions of organic additions on soil quality'* available at www.agricology.co.uk.

iii. Soil biota

Resilient and healthy functioning soil not only has financial benefits for growing crops but is advantageous to organisms that live within the soil biome. A complex structure of soil biology which includes bacteria, protozoa, nematodes, arthropods and earthworms create much of the activity that allows crop nutrients to be more readily recycled. In addition, the symbiotic relationship of fungi and mycorrhizae can help crop growth via their interaction with plant roots, leading to better nutrient utilisation. Reduced cultivations protect the underground soil community from physical damage.

Many studies have deduced that earthworms can improve soil structure through their borrowing and casting, increasing the pore space to allow for better water retention and oxygen movement through the soil. Plant roots are known to exploit the vertical burrows of earthworms. Soil organic matter is fragmented by the ingestion and digestion of the earthworm (Chan, 2001) making it more readily available for further decomposition by other soil microbes and releasing mineral nutrients for use by plants directly. It is therefore widely recognised that earthworms are an indicator of soil quality (Edwards, 2004).

Encouraging crop pest predators such as carabid beetles, whose diet can include slugs, is advantageous to growers. Cropping and cultivation systems aiming for higher organic matter through cover, catch and companion cropping may attract more crop pests. Crop type affects the carabid assemblage indirectly through cultivation practices and microclimatic changes. Any soil cultivation affects the carabid numbers, but studies comparing ploughing with reduced tillage have shown inconclusive results (Holland and Luff, 2000). Finer seedbeds and deeper drilling can also be used to combat field slugs.

'A full report on soil biology appears in the Frank Parkinson Agricultural Trust commissioned report '*The role of soil biology in crop nutrition'* available at www.agricology.co.uk.

iv. Erosion, drainage and moisture retention

Reducing non-inversion cultivations does leave more 'harvested crop residues', which helps hold the soil surface together. The least amount of soil disturbance in the cultivation regime, the less the likelihood of erosion. Sometimes better water infiltration and soil aeration is achieved if there is some loosening of the soil. The low disturbance sub-soiler shown below illustrates this.

In general, soils vulnerable to erosion benefit from reduced tillage and soil losses from farmed fields are minimised. The effect being more pronounced in spring sown crops (Leake & Lane, 2009).

The key to any reduced cultivation regime is to ensure drainage on heavy soils is adequate. Soils that lie wet will develop anaerobic conditions denying crop roots much of the air they require. Weeds such as blackgrass thrive in wet heavy soils where drainage is an issue, so ditches and drains should be maintained to maximise the benefits of a reduced tillage regime.

Increasing the water holding capacity of soils helps with flooding but also can help in times of drought. Reduced cultivation practices can be extremely important when moisture is critical to crop emergence in dry autumns. Some soils can lose significant amounts of moisture, within hours of cultivation, which is crucial to crop germination and establishment.

b. Nutrients and emissions

Reducing the intensity of soil cultivation lowers energy consumption and the emission of carbon dioxide, while carbon sequestration is raised through the increase in soil organic matter (SOM) (Holland, 2004).

Carbon sequestration tends not to increase to depth with no-till but it does increase near the surface (0-30cm). Higher greenhouse gas emissions, particularly N2O, on poorly drained soils, may counterbalance increased carbon sequestration, so that no-till may have a negative effect on carbon foot printing (USDA, 2011).

As mentioned earlier the availability of nutrients for crop growth is much more likely to be achieved in well structured, active and higher organic matter soils. It is important to understand the role of the cation exchange capacity of soils and the role of pH plays in achieving balanced crop nutrition. PH is a logarithmic measure of hydrogen ion concentration and is a figure expressing the acidity or alkalinity of a solution on a scale, where 7 is neutral, lower values are more acid and higher values more alkaline. The acidity of soil and the manipulation of elements and the exchange process that occurs in solution between the pores works best where structure, organic matter and soil biota complement each other.

Improvements to soil structure also reduce the risk of runoff and pollution to surface waters with sediment, pesticides and nutrients (Holland, 2004). A study by Leake & Lane (2009) showed less nitrogen and phosphorous run off from reduced cultivations.

c. Biodiversity

A range of wildlife species can benefit from a reduced cultivation regime;

- Reduced tillage tends to leave more weed and spilt seeds, which is an advantage to seed eating farmland birds (Jones et al., 2006).
- Aquatic biodiversity tends to improve as crop cultivations decrease (Barton & Farmer 1997), as less soil and associated nutrients enters freshwater. Streams and rivers in agricultural catchments usually remain in good condition until 30-50% of the area is cultivated (Donahue et al., 2006).
- The greater availability of crop residues and weed seeds improves food supplies not only for birds, but insects and small mammals (Holland, 2004).

At the Allerton Project, reduced cultivations systems run in conjunction with spring and cover cropping. Increases in earthworm numbers, which aid water infiltration, have helped improve soil structure. However, there are some significant challenges! Slugs, aphids and certain nematodes can thrive within reduced tillage environments. Management techniques to reduce their impact on following crops in the rotation can be found in the Frank Parkinson Agricultural Trust commissioned report '*Biological Control of Crop Pests'* available at www.agricology.co.uk.These control methods can complement more conventional approaches which are widely used in UK agriculture.

The environmental benefits shown from the SOWAP (Leake & Lane, 2009) studies at the Allerton Project could become increasingly important if such environmental soil management continues to attract financial support, to growers, from both the EU Common Agricultural Policy and national governments.

5. Conclusions

Reducing cultivations offers opportunities for growers to save costs and improve crop margins. The factors that influence the economics of reduced tillage are numerous and varied. In principle, the less passes made with a cultivator, the lower the fixed costs. However, soil structure, seedbed preparation, crop establishment along with pest control needs increased management for margins to be maintained. Grass weed control costs can escalate and effect gross margins, if a complimentary cultural and chemical strategy is not implemented.

The importance of soil biology through earthworms, beneficial nematodes and bacteria demands a better understanding on carbon and nitrogen recycling. Plant root growth and relationships with fungi such as mycorrhiza are delicate and can be effected by crop choice, cover crops and plant protection products. Increases in soil biota, through less physical disturbance to the soil, can increase nutrient recycling and help reduce leaching. Reduced tillage that leads to an increase in surface crop residues, helps farmland birds, aquatic biodiversity, mammals and insects. Greenhouse gas emissions of carbon dioxide can be reduced with less cultivation, but careful management of soil is required to minimise an increase of nitrous oxide.

Reduced tillage neatly dove tails into integrated farm management, conservation agriculture and sustainable intensification, which can form the foundations for future crop production. Soil management and tillage regimes will continue to be part of future domestic agricultural policy.

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