GREATSOILS

Arable soil management

Cultivation and crop establishment

Contents

Main contributors: Andy Newbold and Philip Wright

Other contributors: Amanda Bennett, Alice Sin,
Mark Stalham, Anne Stone and Harry Henderson

Photographic credits (see page 35)

Introduction

This guide covers the unique elements of soil management associated with cultivation and crop establishment in arable systems. It builds upon the foundations laid in the AHDB Principles of soil management guide, which relates to any soil-based system. Specifically, this publication focuses on the practical elements that can be controlled, while working within the bounds of those things that cannot, such as weather and soil type.

Management strategies should focus on the development of healthy soils. Such soils are inherently more resilient and offer greater flexibility.

In this publication, sections on drainage, residues, cover and catch crops, trafficking and irrigation outline the major factors to consider in holistic soil management. Finally, the publication includes an overview of cultivation and crop establishment options and presents the strengths and weaknesses associated with each cultivation system.

Developed for use alongside this publication, the establishment approach assessment tool brings together the multiple factors required to make better soil management choices. It has been designed to help farmers review the effects of various factors on their soils, which – in turn – can indicate where a change in management approach might be beneficial. This can be done on a field-by-field basis, taking into account the crops in rotation, as well as across the whole farm.

For a soil to be healthy, its biological, chemical and physical components must be in balance. The AHDB guide ***Principles of soil management*** provides comprehensive information on healthy soils: **ahdb.org.uk/soil–principles**

Soil management factors

Cultivation choice cannot be prescriptive. Certainly, a single approach will not suit all situations. This section describes the key factors of soil management to consider when making cultivation and establishment decisions.

In this guide, 'cultivation' means any mechanical act to prepare or work soil to raise crops.

Many factors that influence soils are relatively fixed, such as climate (especially rainfall) and soil type. Nevertheless, it is critical to understand these factors because they often set boundaries and influence the optimum approach required. Other factors, such as trafficking policy and irrigation, are easier to influence.

Rainfall

Higher rainfall areas will require more management and drainage capacity. Soils in these areas are at greater risk of slumping. Shorter working windows will demand higher machine capacity, but not higher machine weight. Often, a solution is to work for long hours with lighter equipment. Drier areas are more forgiving, with wider working windows often being available.

Soil type

In terms of soil type, it is essential to understand the soil's natural capability to 'repair' or self-structure itself. Some soils, such as sands and silts that are prone to slumping, often benefit from mechanical intervention – even where cover crops are used. However, mechanical stirring of soil can compromise natural soil structure. It can compact and shear aggregates, fill pore spaces, and speed up the decay and oxidation of organic matter.

Often, self-structuring soils:

- Are well-drained
- Are composed of highly stable aggregates that can withstand breakdown (by water and wind)
- Have a calcareous loamy or clay loam texture
- Have good organic matter content and biological activity

Often, less well self-structuring soils:

- Are based on alluvial deposit, often high in sodium content
- Have significant sand or silt content
- Are low in calcareous content
- Are situated on steep slopes (especially in areas of high or highly concentrated rainfall)

Overworked soils are more prone to slumping and capping, particularly if the soil has high silt content. Repeated cultivation, especially at the same depth, also causes compacted zones that restrict water and root passage. The extent of damage depends on the type and severity of cultivation and the condition of the soil – whether wet or dry, hard, soft or loose.

Although intensively worked soils can cure short-term issues (for example, weeds and poor seed-to-soil contact), the approach is costly in terms of labour and machinery. The goal should be to adopt the least disruptive cultivation approaches possible. In particular, well-drained, heavy restructuring and – especially – light self-restructuring soils lend themselves to minimal or no-till cropping systems.

Management (requirements/capabilities)

Successful soil management requires attention to detail, flexibility in management and a solid knowledge of the longer-term implications of any change to practice. Management time pressures often dictate the amount of attention paid to detail: a reduction in soil movement requires closer attention to detail and crop husbandry skills available from the manager.

Drainage

Drainage is the cornerstone of good soil management. Well-drained fields rapidly remove excess water and reduce or eliminate waterlogging. Such fields return fastest to field capacity. Effective drainage requires an unbroken chain of water movement, from the ground surface to where it exits the farm. Freely draining land provides the widest window for effective cultivations and crop establishment. Frequently, headlands and field corners require the most attention.

The AHDB ***Field drainage guide*** outlines the basic principles of field drainage. It includes information about installation and maintenance.

Mole ploughing

Unlined channels formed in a clay subsoil, called mole drains, can improve natural drainage, as they conduct water to permanent pipe drains or open ditches. They are formed by dragging a 'bullet' (a cylindrical implement with a tapered nose) followed by an expander (a cylindrical plug with a slightly larger diameter than the bullet) through the soil to form a circular semi-permanent channel (Figure 1).

Figure 1. Mole drains are formed by dragging a 'bullet' followed by an expander through the soil to form a circular semi-permanent channel

Mole drains are particularly useful on heavy or calcareous clay subsoils that would otherwise require uneconomically closely spaced pipes. However, they are not suitable in areas of rising groundwater or in flood-prone fields.

For best results, soils should:

- Have a minimum of 30% clay and, ideally, have a gravel backfill above the installed pipework. Clay gives the soil the ability to hold together and reduces the chances of the channel collapsing after the mole is pulled
- Have a sand content less than 30%

Residues

Residue management influences the choice and extent of cultivations needed. The amount of crop residues on the soil surface after harvest depends on the crop. Some crops, such as legumes, sugar beet, oilseed rape and silage maize, usually leave few residues. However, cereals produce high levels of residues, with straw biomass approximately equal to grain yield.

There are often good reasons to remove residues, as they can cause management challenges (for example, unripe barley straw, which is hard to chop and spread) or have greater perceived value if removed (for example, revenue return from straw sales).

The sale of straw can produce useful revenue. However, removing organic material will lead to reduced soil organic matter. It can also make the soil more vulnerable to compaction, especially during wet conditions, which will require mechanical remediation. Organic matter levels can be maintained by cover crops or the addition of compost or farmyard manure (FYM).

Carefully plan straw removal (and how to adapt it), especially in wet conditions. See **ahdb.org.uk/straw**

Effective residue management starts with the combine – and is essential when considering reduced cultivations or direct drilling. Distribute residues as evenly as possible to provide a consistent seedbed for the next crop (Figure 2). Even distribution requires regular maintenance of the combine chopping and spreading system, including the static and rotating knives.

Figure 2. When straw is chopped, aim for an even spread to the full header width

Figure 3. Residue management after harvest: stubble mulcher (left), straw rake (middle) and shallow cultivator (right)

Where residues are not distributed evenly, additional operations may be required to process or spread straw and chaff (Figure 3). This can be advantageous where unripe straw is present. Raking or deeper tillage spreads residues and results in a shallow surface tilth for volunteer and weed germination. The weed species present will influence the extent and timing of stale seedbed cultivations.

Providing the system can cope, long stubbles (harvested by conventional or stripper header) can be left after combining to reduce the volume of loose residues. A direct drill can be used if soil type and condition are appropriate and the following crop is not compromised (Figure 4).

When cultivating or drilling into residues, adjacent tine clearance should be 1.5–2 times the chop length. Vertical clearance from the ground to the chassis or mounting should be 1.5 times the stubble height for minimal blockage. Disc-type machines are less exacting than this, but depend on the disc orientation and size. Some drills can also move loose residues clear of the seeding zone at the time of drilling, therefore, require less pre-cultivation.

Generally, incorporating FYM or other organic amendments improves soil properties. However, removal and spreading operations can result in damage, increasing the need for remedial actions. In such situations, take extra care to minimise ground pressures and associated trafficking effects. Organic amendments may also require surface cultivation, other than when drilling. Regulations cover the incorporation of such materials and may influence the need for specific tillage operations.

Cover and catch crops

Where delayed autumn drilling or spring drilling is practiced, there is an opportunity to use cover and catch crops. Such crops offer multiple benefits, including improving soil structure and preventing erosion, as well as the capture of nutrients, carbon and water. Roots also support natural drainage and residues support earthworm populations. The decaying crop will also add to soil organic matter. It is important to understand what role the cover crop is intended to achieve, when and how it is to be destroyed and any pest or pathogen green bridge issues for the following crop.

Establishment and destruction of cover and catch crops is likely to require additional trafficking and cultivations.

Consider the following:

- **Soil texture –** Clays are better cultivated earlier, when soil conditions are usually drier. Slumping-prone sands and capping-prone silts are usually better cultivated later. Surfaces should be left as coarse as possible (i.e. without compromising establishment and herbicide efficacy) to control costs and the mineralisation of organic matter

Figure 4. Long, anchored stubbles left by stripper heading (left) can be drilled with a suitable direct drill. Note: requires effective chaff spread

Figure 5. Example of residue managers fitted ahead of drill coulters

- **Soil structure –** The soil structuring and moisture cycling capabilities of a cover crop can assist natural soil aggregation and self-structuring. In turn, this enables reduced disturbance drilling of the following crop, as naturally formed surface tilth can exist
- **Crop establishment –** Establish covers as early as possible to gain maximum benefit from sunlight and temperatures. However, ensure soil moisture is adequate for germination
- **Soil disturbance –** When establishing a cover crop (Figure 6), relatively high levels of surface disturbance can encourage grass weeds to germinate. Where weed seeds are left on the soil, moisture levels are often too low for germination
- **Crop management –** Careful choice of seed rates and how the crop is managed will avoid thick cover crop canopies. This will assist any wet/dry tilth-forming actions and allow grass weeds the space to germinate
- **Systems approach –** Long-term trial work has demonstrated that brassica cover crops in shallow non-inversion systems are more likely to give a positive yield response in the following crop than in plough systems

For more information on cover crops, visit **ahdb.org.uk/cover-crops**

Figure 6. Cover crop established into a stubble with a relatively high-disturbance tine drill (top). Main crop drilled into a cover crop with a low-disturbance, disc-based drill (bottom). Both drilling modules can be mounted on the same leading hopper

Trafficking

Where implement or drilling width is low, ground pressure and controlled-trafficking considerations become highly important. Typically, a 4-metre drill pulled by a tractor with 710 mm-wide tyres will traffic almost 40% of the area farmed – and potentially more, after headland turning has been taken into account.

Ground pressures

Ground pressures exerted by tractors and trailed machinery determine the severity of soil structure damage, which is largely caused by reduction in porosity. Appropriate choice of tyres and/or tracks can reduce damage associated with higher axle loads (equipment weight). It can also improve fuel efficiency and overall machine output. High axle loads push compaction deeper throughout the profile, which is harder to remedy. Consider the following.

- Determine the appropriate ballasted weight for each operation, including the split between front and rear axles on wheeled tractors. Tracked vehicles must also be ballasted appropriately, so the tracks are in even ground contact from the front to the rear. Correctly ballasted machines will maximise tractive efficiency and keep wheel/track slip low
- Trailed equipment allows the tractor to be optimally ballasted to pull the implement. Mounted equipment can require additional ballast to maintain stability on headland turns and for transportation. Poorly ballasted equipment increases risks of headland compaction from the rear axle and in-field compaction from the front axle
- Set tyre pressures once the ballasted weights are determined (Figure 7)

Figure 7: Use weigh cells to determine the maximum ballasted axle loadings for various operations. Once done, adjust tyre pressures accordingly. This is also important for the front tyres on half-tracked tractors, which can otherwise exert high pressures

- Tyre manufacturers will check and confirm safe operating pressures for a particular application. If any doubt exists, use these services
- Improved flex, very high flex and hyperflex carcase tyre technologies allow reduced pressures (and reduced ballasted weights) to be used. This, in turn, reduces applied stresses, slippage and compaction
- Usually, field pressures are lower than those used for the road. Central tyre inflation systems (CTIS) are available on some tractors for which road transportation speeds and loads require high pressures. This allows reduced field pressures to be easily controlled (Figure 8)

Estimate the risk of soil compaction from axle loadings at **terranimo.uk**

Controlled-traffic farming (CTF)

Controlled-traffic farming (CTF) uses global positioning system (GPS) guidance and combines matched tillage and drilling widths. It puts cultivation, seed drill, combine harvester and crop sprayer passes into dedicated pathways. This minimises in-field wheel tracks and can reduce the area of soil damaged by heavy or repeated agricultural machinery passes on the land. Tillage, drilling and harvesting widths are exactly divisible into the sprayer width (for example, a 9-m cut combine and drill with a 36-m sprayer).

Avoiding random passes should be a matter of course, even when a 'full' CTF approach is not used. In most cases, adopting CTF reduces the need for cultivations, because fewer remedial actions are required. Under CTF, only specific passes are required. In turn, specific passes to manage compaction in tramlines (for example, in-filling or loosening for drainage) or intermediate wheel-ways (for example, loosening or levelling) can be all that is occasionally needed. Consider the following:

- If required, loosen permanent tramlines, from either side, with staggered tines. This encourages moisture away from the middle of each wheeling and avoids 'wet' tramlines (Figure 9). This also forms a profile at depth to move water to the sides
- If possible, loosening intermediate wheel-ways should also be either side of the drill tractor wheelings. This helps to avoid re-consolidation when drilling follows loosening
- Remove non-permanent trackways by lifting directly down the track centres, as crop roots will grow in these areas in the following season
- Other surface indenting/lifting tillage units are available to promote water movement away from tramline centres and into the growing crop areas
- Unidirectional cultivations can lead to levelness issues over time. If an oblique pass is needed to manage inconsistencies of residues or in the ground surface, ensure this is carried out when the soil is dry and by using the lowest possible ground pressure and tractor weight

The combination of CTF with low ground pressures can reduce the need for remedial tillage and enable direct drilling, when appropriate

Figure 8. Retro-fit central tyre inflation system (CTIS) options (left, top and bottom) and original-fit, fully integrated CTIS (right)

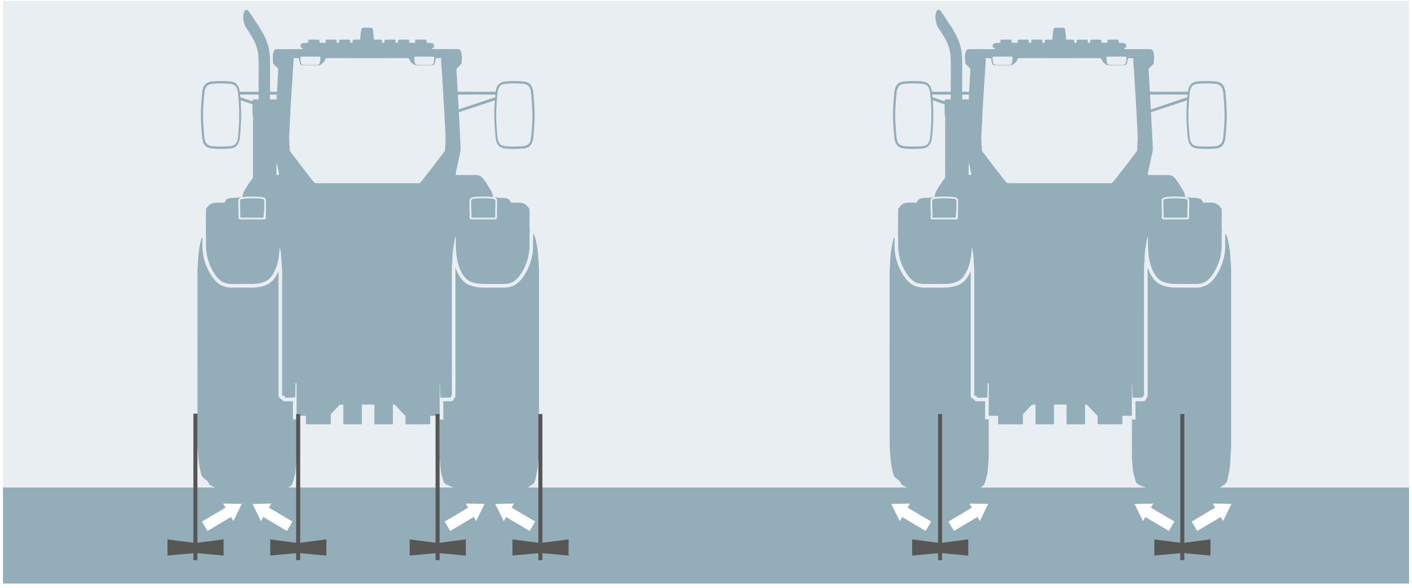


Figure 9. Loosen each side of permanent wheel-ways or along tracks

Figure 10. Controlled-traffic farming (CTF) provides many advantages

Irrigation

The free-draining soils often used for root crop production are easy to work. However, such soils are less likely to repair naturally or to self-structure. Regular irrigation on such soils can reduce soil particulate adhesion. It can lead to slumping, soil degradation, run-off and loss of soil structure. High levels of organic matter are also difficult to maintain.

Where irrigation is applied to poorly structured soils, keep soil moisture 20–30 mm below field capacity.

Where bare soil is irrigated, keep the droplet size as small as possible (application rates not greater than 5 mm per hour) to minimise capping risk. Coordinate field operations so that soil moisture deficit (SMD) is greatest when working and steadily increase SMD when approaching harvest to allow harvesting operations.

See the AHDB guide ***Seasonal water management for potatoes*** for further information on irrigation methods.

Weeds

Cultivation is not just about crop establishment: it also changes weed populations. The gap from harvest to drilling provides several opportunities and benefits for weed management.

Annual meadow grass, rye-grass, brome and black-grass are difficult to manage in a reduced or no-till system, particularly in short windows between crops.

Inversion tillage can be used as part of an integrated weed management strategy, especially where herbicide-resistant grass weeds are present or when weed populations are high (with the exception of wild oats). The extent of seed burial and mixing influences weed numbers. Ploughing buries residues and surface weed seeds, such as black-grass or sterile brome. It can, along with deep cultivation, limit the effect of persistent herbicides to a following crop. However, subsequent ploughing will cause some weed seeds to resurface.

Use the plough alongside other appropriate tillage in response to the current situation and weed burden. For example, shallow cultivate generally (to minimise surface disturbance) and plough occasionally (once in every 5 years or more). High levels of surface disturbance mixes weed seeds throughout the profile. Some of these seeds can germinate and make control difficult in subsequent crops.

Pests

Short rotations, cloddy seedbeds and crop residues promote slug activity. Green bridge issues can host pests ready for a susceptible following crop. Develop a rotation to disrupt pest life cycles.

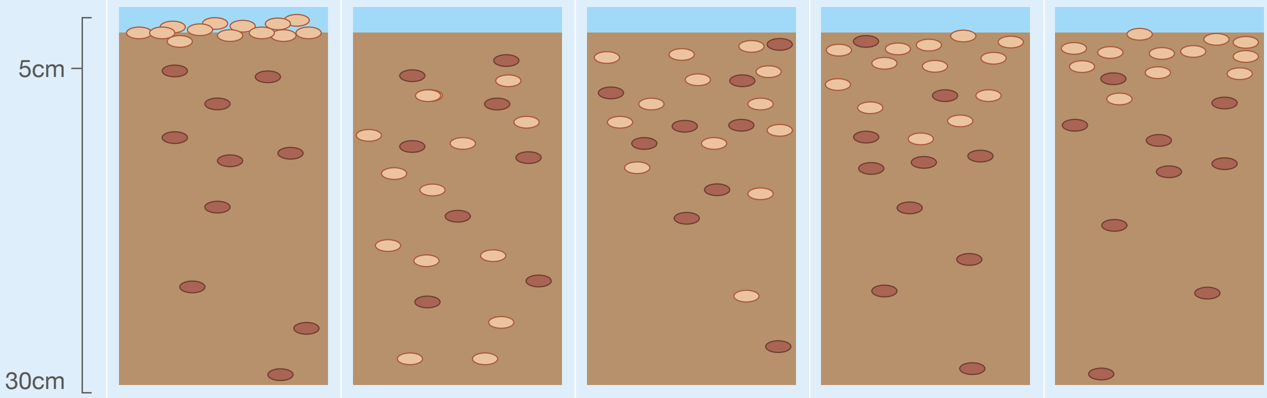
Direct drilling and delayed drilling increase the risk of slug damage. Open, damp and cloddy seedbeds allow slugs to move easily and provide more shelter than friable, frequently cultivated soils.

Seedbed preparation and quality are potentially more important than the chemical control of slugs, particularly in combinable crops. Ploughing is a good way to reduce slug populations, but even minimum tillage gives a considerable reduction in slug damage compared to direct drilling. Seedbed cultivations will increase mortality depending on machine action, soil type, cultivation timing, depth and intensity.

Firm seedbeds reduce slug activity because it is harder for slugs to move around and reduces the availability of safe resting places. A fine, consolidated seedbed protects seeds and prevents slugs from accessing seedlings before emergence. A consolidated seedbed provides good seed-to-soil contact and enables seeds to germinate quickly and grow rapidly through the vulnerable establishment stage.

Table 1. Cultivation options and effect on weed seedbank

Cultivation	After harvest	Plough	Deep till	Shallow till	No-till
Soil movement	Not applicable	Inversion	Deep	Little	No mixing
Cultivations depth (typical depths)	Not applicable	20–40 cm	20–35 cm	5–10 cm	None
Soil depth		Many old seeds brought to surface, most new seeds buried	Fewer old seeds brought to surface, some new seeds buried	Very few old seeds brought to surface, few seeds added to the sandbank	A few seeds may change layers
Weed control		Generally reduces weed populations	Has little effect on weed populations	Keeps weed seeds in top 5 cm of soil where they can germinate	Keep weed seeds in top 5 cm of soil where they can germinate



Cultivation and crop establishment options

Many factors influence the need to cultivate or restructure soils. These can include the need to create conditions for crop establishment and growth; to cope with pests, weeds and residues; or to alleviate compaction or consolidation. Cultivation costs depend on equipment, fuel and time used. All considerations must be balanced against effects on crop yield and quality, timeliness and long-term effects on the soil and the environment.

Any barrier in the soil that limits water, air and root movement can reduce yield. Often, a careful combination of 'roots and metal' is the most efficient way to improve soil structure. Deep, vigorous root systems are more likely to develop in well-structured soils. This can then lead to a virtuous circle of improving soil quality.

In considering soil management options, it is worth bearing in mind that soil type and texture can play an important role in determining what is feasible and economically viable.

Basic principles of soil–metal interactions: moisture

Fundamental moisture principles govern the interactions between soil and metal for all forms of cultivation: deep, shallow or reduced. Soil moisture content should be assessed to ensure it is appropriate for cultivation. To assess soil moisture, use a ribbon test on a sample from the soil surface and at cultivation depth.

Consider the following.

- Avoid working the soil when plastic conditions are on the soil surface (to minimise traffic damage) and at cultivation depth (unless mole draining)
- Friable (crumbly) conditions are best for cultivations to break down clods into a seedbed
- Increased clod breakdown occurs when friable soil is firm or pressed
- Where soil is too dry to form a ribbon, clods do not tend to break down easily and moisture is usually insufficient for germination
- Moisture between friable and dry is best for soil loosening, where brittle, tensile failure is needed to create cracks or fissures

Figure 11. Fundamental moisture principles govern the interactions between soil and metal

Sub-surface restructuring, including subsoiling

Figure 12. Typical examples of tillage-based 'pans', or barriers to water and root passage, caused by repeated cultivations at the same depth

Dig through moist subsoil in a crop to identify potential issues (Figure 12). Compaction signs include:

- Obvious differences in soil moisture and root growth at any common depth
- Absence of visible porosity, including fissures and root channels (which should mainly extend in a vertical direction to allow free passage of water, air and roots)

Reassess any zone with signs of compaction after harvest, as roots can repair damage. Where damage remains, take remedial action.

Careful assessment of compaction is needed. See ***thinksoils*** for guidance on how to examine various soils in the field: **ahdb.org.uk/greatsoils**

When loosening the soil, consider:

- Setting loosening tines to achieve vertical fissures through the compacted layers, with minimal disturbance of the profile
- Only loosening the affected area (for example, turning headlands or specific soil textures)
- Ensuring appropriate soil moisture levels at and above the loosening depth to 'stretch' soils and create vertical fissures (Figure 11 and Figure 14, left)
- Not loosening to depths greater than required and consider the actions of roots
- An increase in loosening depth of 5 cm, which can double the fuel use. Doubling loosening depth can quadruple the draft loads
- Avoiding the use of deep loosening wings with high lift at shallow depths – excessive soil movement and destabilisation of the profile can result
- Avoiding aggressive loosening actions that cause a loss of natural structure and aggregation at depth. In turn, loosened profiles can then rapidly re-consolidate, losing any beneficial effects
- Using reduced-disturbance actions to reduce mixing of weed seeds through the soil profile
- Establishing a crop as soon as possible through loosened soil to stabilise it
- Loosening through a cover or catch crop, if root growth appears restricted (Figure 13)

Figure 13. Soil loosening through a growing cover crop

Assess the impact of soil loosening on compacted layers (i.e. look for vertical fissures) and adjust settings, if required.

The following affect soil loosening:

- Geometry of loosening components (Figure 14) – steeper rake angles shear or compress, shallower angles lift and loosen (see also Figure 22)
- Vertical lift height of wings (too great) – structure is completely rearranged and natural column strength is lost. Examples include conventional, deep subsoilers with high wing lift operated at shallow depths
- Vertical lift height of wings (too little) – vertical fissures are not created through compacted layers. Examples include low disturbance looseners operated at subsoiling depth
- Tine design – forward inclined tines at the surface can reduce disruption
- Speed of operation – faster speeds imply reduced lift height is needed
- Pre-cultivations – reduce lifting requirements for following deeper tines. For example, shallow tillage ahead of loosening
- Leading discs (aligned to the tines) – can reduce surface disturbance and cut surface residues and roots, allowing these to pass by the tines most efficiently
- Rear roller action – determines the field finish and consolidates the soil profile to working depth. This maintains surface stability and minimises excessive oxidation of organic matter by closing the soil surface in a controlled manner

Where more lift is required for fissuring, aim to increase the length of the lifting parts (for more wing lift height), rather than their rake angle. Set the wing leading edge below the depth of compaction by 2–3 cm and allow for local field variability. Where greater variations occur (for example, deeply compacted headlands), adjust the machine to the areas managed.

Do not reduce lift too much to achieve minimal surface disturbance. This can make restructuring ineffective. Check that vertical fissures, not a compressed channel, have been created throughout the compacted layers.

Low surface disturbance, allied to effective fissuring for depths between 15 cm and 30 cm, can usually be achieved by a grassland-type sward lifter operation (Figure 15). Curved or sideways-inclined legs can also be effective, especially in shallower situations, as the natural soil fissuring angle (from the point tip) is used for the leg to pass through cleanly.

Figure 15. A sward lifter

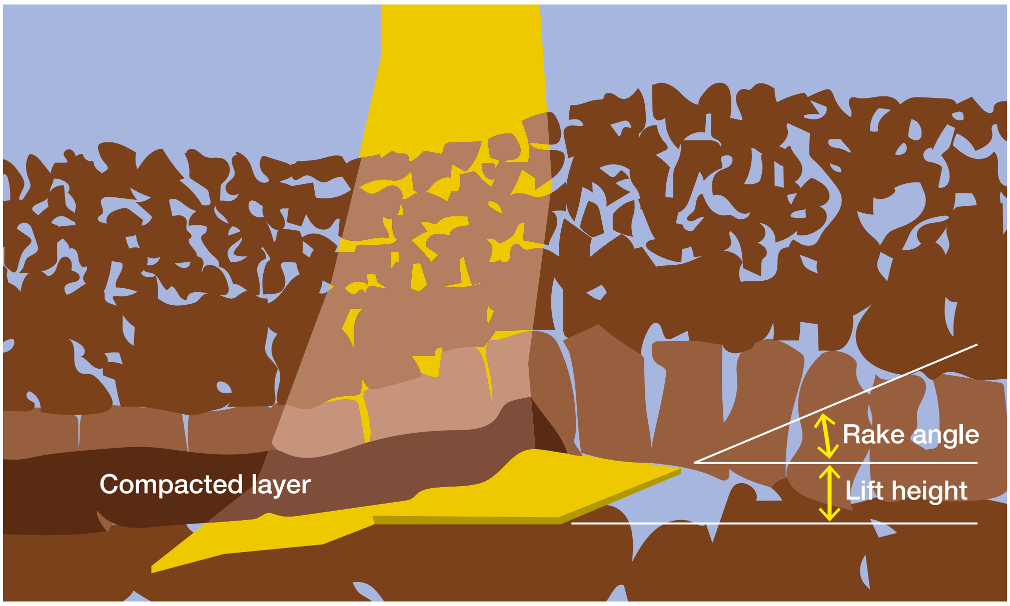


Figure 14. Geometry of loosening parts and minimal surface disturbance (left). Sufficient lift to create vertical fissures is needed at the problem depth. Low rake angles minimise surface disruption and heave, provided lift height is adequate for fissure creation. Sideways inclined legs (right) can also minimise surface disturbance, provided operational speeds are appropriate

Soil type influences soil loosening. Sandy soils loosen effectively when moist, unlike higher clay content soils. Leave silty soils, which are prone to capping and settlement and sandy soils, which are prone to slumping, until later in the year. This will help to avoid re-consolidation before roots can stabilise the soil.

Extremes of weather also affects the need for loosening (Figures 16–18). On shrinking clay soils, a dry season can produce effective fissures without needing deep cultivations. Here, shallow surface tillage to move small clods into such cracks will create more fissures when the soils swell. This creates a longer-term, stable series of natural cracks to assist root passage.

For further information on subsoiling in potatoes, see page 26.

Figure 16. Shallow surface tillage places clods into shrinkage cracks

Figure 17. Natural cracks in a clay loam (left). A crack in damper, calcareous clay, partially closed by small clods after shallow surface discing (right)

Figure 18. Mechanically formed fissures subsequently direct-drilled and now stabilised by roots

Ploughing

It is necessary to plough some soils every year and others when conditions are unsuitable for reduced cultivations. Some soils do not need to be ploughed. The rotation also dictates the need to plough.

Timely ploughing can reduce compaction. It can also reduce capping and slumping on silty and sandy soils, as long as they are not overworked. Ploughing is often the most robust and expensive option, usually involving pressing and secondary tillage before drilling.

Although plough-based systems often produce good soil physical conditions in the short term, they can degrade soils over time.

Ploughing: best practice

A poorly planned ploughing operation wastes time and energy. It can also cause unintended soil damage. Ensure conditions, plough setting and timing are appropriate. Choose subsequent cultivations to suit the soil type, time of year and following crop.
When ploughing, consider:

- Setting skimmers to effectively bury trash
- Controlling speed to produce the best finish
- Choosing a plough depth to suit the soil type, not tractor capacity
- Ensuring that the share width is less than the furrow width
- If and when to press
- Subsoiling where deeper loosening is needed
- Choosing whether to subsoil then plough, or plough then subsoil. Set the plough for effective burial and levelness for even settlement. Note: the subsoiler rear packer roll provides a secondary tillage and weather-proofing action, where this operation follows the plough
- Using loosening units on plough bodies (Figure 19) where soil depth and stone content are not limiting. Loosening can be on alternate bodies or each body, but should only be used where needed. Avoid plough body looseners where soil moisture levels at and beneath plough depth are plastic (Figure 11)

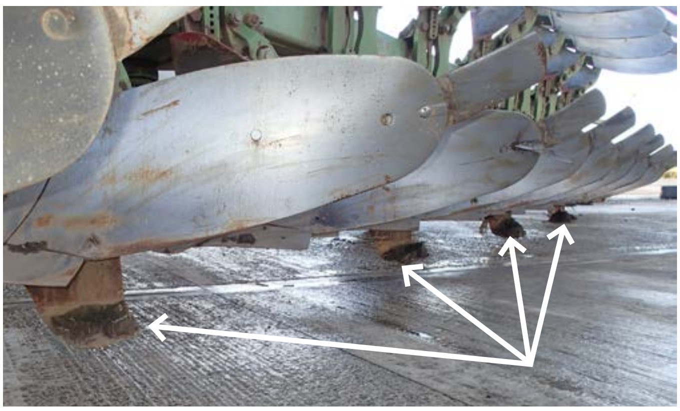


Figure 19: Looseners (see arrows) fitted to alternate plough bodies below the share depth

- A semi-mounted option, if choosing a large plough, to prevent excessive compaction on headland turns
- Pressing with or after ploughing – this has many advantages (Figure 20)

Figure 20. Pressing a ploughed field has many advantages

Pressing with or after ploughing

Pressing a ploughed field has many advantages. It:

- Consolidates soil to a depth that better supports traffic
- Increases bulk strength, which allows more efficient seedbed preparation and clod breakdown
- Can provide a 'halfway-to-a-seedbed' surface and make subsequent operations more efficient
- Reduces loss of organic matter through oxidation
- Allows management of the time delay for weathering. Note: set tyre pressures and axle loads as low as safely possible to avoid damage
- Gives a corrugated, weatherproof surface that is faster drying and takes moisture through more efficiently by capillary action

Ensure soil moisture is in the friable range and avoid pressing slumping-prone soils, unless drilling or planting is imminent.

Ploughing: weather considerations

Although worked soil can speed up drying, such soil has greater pore capacity and holds more rain. If dry soil is ploughed, it minimises structural damage and can drain quicker.

Early autumn-ploughed soil has more natural drainage channels and is usually is drier in spring. The exception to this is on slumping-prone soils (such as silts and sands), which respond better to later ploughing, followed by immediate cultivation.

In high rainfall regions, especially in spring, ploughing immediately before cultivation and drilling often produces a better seedbed. This is because soil is drier in this zone when cultivating. Regional climatic effects, therefore, need careful consideration when looking at alternative establishment options.

Soils with high silt and clay content need operations to be very careful timed. It can be impossible to achieve a satisfactory tilth on soils that are either too dry or too wet. This increases clod formation (and compaction risk in damper situations), especially after ploughing.

Ploughing wet soil can result in severe structural problems, especially if there is soil surface compaction from previous cropping. This causes soil to invert as a continuous slice, which can form an anaerobic layer at the plough-share depth.

If the tractor wheel runs in the base of the furrow, wheel slip can occur. This form of compaction is greater in wet conditions or with high draft forces. The plough share can also cause localised soil smearing when wet. This makes the plough-depth layer more resistant to water and root passage. Keep tractor wheels on the surface to reduce compaction (Figure 21), especially when using higher powered tractors (on-land, as opposed to in-furrow). Steering guidance can help.

Figure 21. On-land ploughing to minimise furrow-base damage, compaction and to assist bout matching

Combinable crops – reduced tillage

Reduced cultivations can lower costs, speed up operations and cause less soil damage. However, greater attention to detail is required, including soil assessment, soil consolidation, residue management and weed control. Timeliness and planning are vital. Reduced (non-inversion) tillage is best suited to stable structured soils. Clay or loam soils are particularly suitable, but there have been good results on light calcareous soils. On silty and sandy soils, capping and slumping may cause problems, particularly with direct drilling.

Provided that soil is structurally stable, the soil type is suitable, weather conditions are favourable and weeds can be managed, then reduced cultivation practices, including direct drilling may be suitable.

Reduced tillage soils are better able to resist and rebound from compaction than ploughed soils. Such soils also have a lower risk of soil erosion and run-off. Non-inversion systems can yield as well as – and may be more profitable than – ploughing. Wheat yields are relatively robust across different cultivation systems. However, for other cereals, the yield gains seen in Recommended Lists trials under plough systems may not occur under non-inversion systems because of variety x cultivation interactions.

Non-inversion tillage can promote the accumulation of key nutrients, such as phosphorus (P) and nitrate (NO_3^-), in the surface horizon (where most roots are and biological activity occurs). However, the lack of disturbance can acidify this horizon in the longer term.

If warranted, adjust drilling method, date or seed rate using reduced cultivations. Drill cereals at adequate (usually 4 cm) depth, ensuring good seed to soil contact.

Carbon sequestration

Research at long-term experimental sites found that, based on cultivation approach alone, reduced tillage did not increase the potential of soil to store carbon throughout its profile (60 cm). However, greater carbon content in the soil surface occurred in non-inversion treatments than in inversion treatments. If soils are not sampled to a sufficient depth, differences in carbon distribution could lead to wrong conclusions. Stone content must also be accounted for when assessing soil carbon.

Basic principles of soil–metal interactions: geometry

Fundamental principles of geometry govern the interaction of soil and metal.

- Rake angle (the angle from the ground to the soil engaging part of a tool) largely determines the action on the soil
- Discs and rollers, plus wheels, have high rake angles and can cut or compress the soil and any residues on the surface. Compressive action in plastic conditions smears and compacts the soil. Such components work most effectively in dry to friable conditions
- Tines have high-to-low rake angles:
  - High rake angles can compress and disintegrate clods and minimise surface lifting and disturbance
  - Intermediate rake angles can sort and partially disintegrate clods, pushing them against the bulk strength of the soil ahead. Small aggregates or clods located here can be sorted into the larger gaps present. This creates an ordered tilth with few large open spaces
  - Low rake angles predominantly lift and loosen.
    This action raises soil upwards, putting it into tension where brittle failure or breakages create fissures or cracks. Aggressive lifting (at high speed or with intermediate-to-low rake angles) can cause high disturbance and leave a profile that is more prone to recompaction or slumping
- Low rake angle loosening is suited to dry, friable or slightly damp conditions with low risk of smearing, compared to high rake angle actions. Provided angles are low and speeds are not too high, surface disturbance is minimised and the soil structure retains many columns with vertical fissures between. This assists drainage and can support loads from above with less risk of recompaction

Figure 22. Fundamental principles of geometry govern the interaction of soil and metal

Deep non-inversion tillage

This technique gained popularity in the 1980s and 1990s as a low-cost alternative to ploughing. It developed acceptable conditions at depth and allowed weathered surface tilth to remain nearer the seedbed zone. It was used most frequently on medium and heavy soils in a cereals, pulses and oilseeds rotation (Figure 23). The advent of herbicide-resistant grass weeds and close rotations of cereals and oilseeds, with minimal or no spring cropping, meant detailed changes to such systems have been necessary.

Figure 23. Typical high disturbance, deep non-inversion mixing action

For effective deep non-inversion, consider:

- Identifying problem depths and working just below them
- Minimise surface mixing and manage residues, if appropriate for the following crop
- Using deeper soil structuring actions that protect the natural soil structure, when required. Actions must cause low surface disturbance, produce subtle vertical fissures and not full rearrangement of the profile at depth. Careful selection of loosening tine geometry can help
- That the technique can be effective in a broader rotation, including root or brassica crops, where regular ploughing is not the preferred option
- That some machines combine closer spaced discs for shallower surface residue mixing, have low surface disturbance loosening legs and a rear consolidating press roller (Figure 24). Where a looser finish is needed, depth control can be achieved by the roller, or combined with transportation wheels. Such machines are used where soil loosening is a regular requirement – as dictated by soil type, climate, or cropping, for example

Figure 24. Lower surface disturbance, shallower discing machine option

Two-pass alternative

Two separate operations can be used to selectively deep-structure: one for soil loosening (ideally low surface disturbance) and a second operation to surface-cultivate (before or following the loosening pass). Where possible, loosen after the surface cultivation to remove any adverse effects. The loosening pass can provide added surface cultivation by the rear roller on the loosener.

Shallow non-inversion tillage

Most often used where cereals, pulses and oilseeds are in a rotation, the technique requires the use of CTF and/or low ground pressure technologies to avoid deeper soil damage. The technique is suitable for self-structuring soil types, can help control slugs and forms stale seedbeds (where it is preferred not to leave weed seeds and volunteers on the surface to germinate).

Figure 25: Shallow non-inversion tine and disc-based machine options

For effective shallow non-inversion tillage, consider that:

- Effective residue management is essential
- Good consolidation after cultivations is vital to manage slugs
- Where there is a need for deep soil restructuring, these actions can be by a separate, targeted operation
- The shallow working machine can use tines or discs (or a combination), with depth controlled by the rear roller and, possibly, gauge wheels
- Discs have a high rake angle (Figure 22). They are most effective in drier conditions, and where residues can be high in volume or not finely chopped
- Discs with a wave format give a significant width of cut at very shallow depth and enable full width shallow cultivation (Figure 26)

Figure 26. Wave-type discs on a shallow non-inversion cultivator

Generally, tines have a lower rake angle than discs (Figure 22) and have a wider moisture window of effective operation with less smearing risk. Additionally, if spaced adequately, tines can cope with larger volumes of residues. Multiple rows (four or more) of narrow-tipped tines can move the surface to a shallow depth (Figure 27).

Wider-spaced tines, in fewer ranks with sweep or duck-foot type tips, result in a greater risk of smearing or shearing across the working depth in damper situations. However, they allow the use of a simpler, closer-coupled or shorter design of machine.

Figure 27. Shallow tine-type cultivator with multiple rows of narrow-tipped tines

Strip tillage

This technique cultivates the strip in which the crop grows, rather than the full field. In soils with reduced self-structuring capabilities, strip tillage provides a stepping stone to direct drilling, allowing some mechanical assistance.

Leaving parts of the field undisturbed saves money, retains support for future passes and protects drainage channels.

For effective strip tillage, consider:

- That row width tends to be wider
- That changes to inter-row spacing can affect grass weed competitiveness. Consider if the number of plants per square metre is adequate
- Residue management – the ability to move residues clear of the seeding zone, or to rely on the capabilities of the drill to work into such zones. Often, moving chopped and spread residues clear of the seeding zone is straightforward, given enough clearance between strip-tilled rows for residues to be moved into
- Specialised cultivation and drilling machines, which prepare and drill at different times or can be linked together, as needed (Figure 28)
- That any deeper soil structuring actions must be effective but not disruptive to natural soil structure. Actions must produce subtle vertical fissures and not a full rearrangement of the profile
- Zone-placed fertiliser as an option, if using appropriate tines in the strip cultivation units
- Timing of the tillage and drilling operations – crop and soil type/condition determines whether one (Figure 29) or two operations are needed
  - Two operations – where a spring-sown crop follows autumn strip tillage preparation
  - Two operations – where deeper tillage precedes drilling, this allows the deeper operation to be done earlier, in potentially drier soil to maximise effectiveness
  - One operation – where tillage and drilling are combined, ensure deep loosening is effective, especially in damper conditions (particularly associated with later drilling)

Figure 28. Specialised strip-till cultivation units prepare ground for later drilling

Figure 29. Dedicated all-in-one strip tillage drills

Limit sideways soil movement to the cultivated zones (Figure 30). This reduces risk of volunteers or weed seeds being encouraged inter-row and makes following rolling operations most effective in the seeded zones. Manage such disturbance by:

- Leading discs ahead of tine openers to minimise clods being hit head-on and thrown sideways
- Using low rake angle, shallow lift tine components or openers
- Using disc openers with limited sideways throw (for example, with side gauge wheels) or tine/banding openers with low disturbance capabilities
- Using border discs/side baffles to limit soil throw from the ground engaging parts
- Limiting speed of travel, especially with tine openers

Consider weed management inter-row, either by mechanical (weeder) or chemical (hooded sprayer) means. Companion cropping could also be considered for the zones between the strips. Slug risk can also increase because of the residues remaining in the uncultivated strips – the planted strip may become a 'slug highway'.

Figure 30. Example of leading and side-border discs, with leading residue manager wheels

Combinable crops – one-pass systems

Direct drilling

Direct drilling is often seen as a natural progression after adoption of CTF and/or reduced ground pressure technologies, as these gradually reduce the need for remedial tillage. Similar progressions are reported following adoption of strip tillage.

Direct drilling means the drill alone is used without a prior cultivation pass of any type. Two types of drill can be used:

- Cultivator-type drill, where some soil movement is desired (for example, in slump-prone soils). These are predominantly tine-based
- No-till drill, where as little soil movement as possible is desired. These are predominantly disc-based. No-till is also known as zero-till

Most direct drills in the UK impose some form of tilth-making action in the seed zone. This is done by the openers alone (especially tine-based or disc-based openers with undercut and a seed placement boot or coulter), or by a leading element (for example, tine or disc – the discs are likely to be fluted).

For effective direct drilling, consider:

- Geographical location (including rainfall and topography)
    - Wetter regions, especially with shorter growing seasons, limit opportunities for the natural tilth-making actions that are needed in the absence of tillage
- That soil in good structural condition can be farmed with less remedial tillage
    - Direct drilling is easier to adopt in naturally self-structuring soils
    - Slump-prone soils rely on natural actions (for example, from plant roots, wet/dry and freeze/thaw cycles, stabilising residues and good levels of soil biological activity) to enable continuous direct drilling
- That poorly drained soils have limited windows for natural tilth-forming actions. They compact more easily and may require tillage as a corrective action
- Cropping and rotations – especially where root or vegetable crops are included and where spring crops are regularly grown
    - Direct drilling in spring relies on natural structuring actions to make tilth. Dense surface canopy cover can adversely affect such actions
    - Harvest damage and bed-forming actions (for example, that associated with root crops) can need cultivations to repair
- Weed burden – especially grass weeds. Tillage (especially consolidation) can help manage weeds with a non-selective herbicide

- That occasional strategic tillage may be justified to maximise gross margin (for example, through management of compaction, weeds or residual herbicide effects)

Other management considerations include:

- Specialist machinery requirements – it may be possible to use a flexible drill type or contractor services, as opposed to a specialist purchase
- Residue management – this affects how the crop grows through surface residues. Residue-managing units, allied to each opener, can sweep them clear of the drilled seeds
- Other drill designs, including a combined disc with side coulters (cross slot), manage the position of surface residues and the optimal placement of the seed
- Zone placement of nutrients (N and often P) may be necessary, especially in the first few years
- High levels of surface residue, which can reduce pH levels. pH needs balancing, especially in the surface zone

Direct drill selection

Drill design, including opener type and ground-engaging items (discs, tines or both), needs careful consideration to permit flexibility. Consider:

- Crop type, seed size and placement requirements (depth, spacing)
- Residues (ability to work in residues and avoid placing seeds in contact with residues)
- Soil condition (discs cut and consolidate, tines loosen or sort aggregates)
- Nutrient requirements (for example, need to supplement N and/or P)

Disc-based drills cope with high levels of surface residue. However, the design should avoid 'hair-pinning' high levels of residue into the seeding zone.

Other factors to consider include:

- That the risk of smear is greater from discs, especially in wetter conditions
- The total weight required for disc penetration (increases with disc size)
- Soil closing action – discs, which disturb and throw less soil than tines, need less remedial action to produce a level, consistent surface. Angled disc slots are closed by vertical pressure and vice versa

The opener design is critical. This includes the tilt angle of the disc, the drop tube position (relative to a single disc) and whether twin disc or triple disc openers are used.

If needed, many cultivator drills can be used as a direct drill (cultivation elements raised clear of work) or as a cultivator drill (Figure 31). This flexibility is useful when occasional tillage is required (for example, when ploughing ahead of potatoes, sugar beet or peas).

Tine-based drills can benefit from leading discs. These will cut residues and reduce disturbance. The detailed design of the opener, including its rake or lift angle, is important. This will determine soil movement and closing requirements (see Figures 32–34).

Combining cultivations and drilling into one operation is another way of minimising passes and, in effect, directly drilling into the previous crop stubble

Figure 31. Combined structuring and drilling (left) and cultivator drill used as a direct drill with cultivation elements raised clear of work (right)


Figure 32. Examples of tine-based drills with leading discs. These enable effective operation in higher levels of residues and reduce soil disturbance

Figure 33. Alternative openers for a tine drill to modify the amount and degree of soil disturbance and drilling band width


Figure 34. Angled disc opener (left) and straight disc openers with side gauge wheels (right)

Direct drilling into standing straw stubble after a stripper header is another technique providing flexibility for establishment with minimal cultivations and soil disturbance. The drill, in all cases, needs to be suitable.

No-till

Also known as zero-till, no-till is associated with a low level of soil disruption. Its most powerful benefit is that it improves soil biological fertility, which can help make soils more resilient. The practice can also promote diversity and abundance of soil life. However, it is important to note that this can include an increase in organisms associated with plant diseases.

A farm's suitability for no-till is influenced by the climate, soil and crops. The approach requires thorough research on equipment choice and a high standard of crop and soil husbandry. No-till is more likely to be successful in stable-structured (compaction-resistant) soils, such as self-structuring calcareous clays, in lower rainfall areas. Good drainage is essential. However, the structure of sandy and sandy loam soils, especially if low in organic matter, may be unstable, thus may need occasional loosening.

In a no-till system, 30–100% of the surface is covered with residue and can reduce or eliminate soil erosion. The drill must penetrate the seedbed and place seed accurately without smearing. It also requires good seed-to-soil contact. Drills should be set to ensure that crop residues and planted seeds are not in close proximity. Otherwise, this can increase fungal contamination in wet conditions and delay germination as a result of poor seed-to-soil contact in dry conditions. If seed-to-soil contact remains unsatisfactory after drilling, consider rolling to lessen the risk of crop failure.

Aggregates and soil above the seed determine the depth of seed placement and, critically, evenness of emergence. Soil cover also forms a barrier to seedbed-applied herbicides. After drilling, consolidation is important.

The presence of crop residues keeps the soil cooler and wetter than bare ploughed soil. This can result in delayed drilling of spring crops. Crop residues on the soil surface can affect the drilling operation and reduce the evaporation of water from the surface.

No-till can give annual yields of combinable crops within 5% (above and below) of those after ploughing, but there is greater seasonal variability in yield. Yields are most variable in the first few years of a no-till system. Immediately after adopting no-till, crop yields may be appreciably lower than after ploughing, but tend to increase as soil structural conditions improve. With no-till, soils with poor drainage and weak structure generally give lower yields than after ploughing.

Potential yield-reducing factors in no-till systems include:

- No incorporation of crop residues
- An increase in grass weeds and volunteers
- Topsoil compaction from previous harvest traffic before soil strength and bearing capacity has increased, especially when associated with poor drainage
- Limited time for the build-up of soil structure-improving factors (for example, accumulation of organic matter)
- Reduced N availability
- Increased levels of slug damage

Changes to soil properties under no-till include:

- Accumulation of organic matter near the soil surface and increased structural stability (resistance to erosion and mechanical actions) and biological activity. After several seasons, this this may lead to a reduced N requirement
- Improved self-structuring at the surface, especially when calcareous, as well as greater water permeability. The lack of disturbance causes bulk density to increase in the top 25 cm of soil. This can give a wider window for field work, but can also lead to poor aeration and cooler, wetter conditions at the surface. Changes in some properties after the introduction of no-till may be seen within a few months (bulk density, soil strength) or take several years (organic matter levels)
- Acidification at the soil surface as a result of direct drilling. The pH of the surface soil can decrease to the extent that it contributes to further soil structural deterioration and limits plant productivity
- Reduced likelihood of soil erosion and run-off with loss of particulate P, attributed to the lack of soil disturbance and presence of crop residues. Direct drilling is, therefore, a good means of reducing the risk of nutrient losses by run-off from slopes adjacent to freshwater bodies that are prone to eutrophication. However, the content of phosphate may increase near the surface, leading to risks of nutrient loss if run-off ever occurs

Broadcasting

This is a means of establishment of cover/catch crops and crops with small seed (for example, oilseed rape) directly with or before the combine (Figure 35).

For effective broadcasting, consider:

- Ensuring that residues are evenly chopped and spread, as thick accumulations cause uneven establishment
- That yield can be affected by compromised establishment; nutrient availability/lock-up; and increased slug, disease or carry-over pressures
- The risk of residual herbicide from the previous crop – this may dictate the choice of cover species capable of establishment and the need for cultivations
- Compaction caused at harvest – use CTF and options to minimise ground pressures
- Restructuring soil after establishment, if establishing a cover or catch crop, if conditions are suitable and disturbance is managed
- Broadcasting into the previous crop, which maximises the time for a catch, cover or conventional crop to grow. Such benefits are critical when harvest is delayed or resources are limited. If broadcasting a mix, be aware that heavier seeds travel further from a disc-based spreader than lighter ones. Boom-type spreaders are ideal

Figure 35. Combine-mounted distributor

Potatoes: primary tillage

During potato production, the short work window for cultivations when soil moisture is right means it is particularly important to minimise soil structure damage at each specific cultivation depth and by associated trafficking (Figure 36).

Compaction zones

Zone ❶ Compaction pan below plough depth
Zone ❷ Compaction pan just above plough depth
Zone ❸ Compaction in wheelings
Zone ❹ Compaction at the base of the ridge
Zone ❺ Compaction below the tuber
Zone ❻ Compaction of the ridge (‘capping’)

Zone 1 and 2

Ploughing wet soil or previous cropping operations can cause a compaction pan below the plough depth (Zone 1). Bed tiller or separator operations can cause compaction just above plough depth (Zone 2).

If soil moisture allows it, prioritise the management of compaction in these zones. This requires a targeted approach, both field-by-field and within fields, as compaction depths vary. Loosening (wing leading edge) depth should be set 2–3 cm below compaction depth.

Zone 2

Seedbed cultivation depths should, by default, be set to the shallowest possible, provided there is no detrimental effect on seedbeds, yield or quality.

To avoid shallow compaction, set up bed tilling and destoning or declodding operations carefully.

In particular:

- Assess moisture at depth when setting up all kit. Often, working shallower and waiting for drier conditions will produce better tilth with fewer clods and reduced barriers to roots and water infiltration
- Adjust bed-forming machinery (where additional tilth is needed). Although counterintuitive, working shallower in the first instance is appropriate. Deeper soil is wetter and more likely to produce more clods

Zones 3 and 4

In addition to Zone 2, compaction can occur in the wheelings (Zone 3) and at the base of the ridge (Zone 4). Compaction in these zones is common, but must be avoided. Both forms prevent water from entering the soil and increase run-off risk. Management should prevent compaction from extending under the bed. In addition to controlled traffic, minimise tyre/track pressures, especially for the final seedbed cultivation passes.

Zone 5

Shallow compaction beneath planted seed can have the largest influence on root growth and yield. Opening coulters on the planter can often introduce compaction immediately below the tuber.

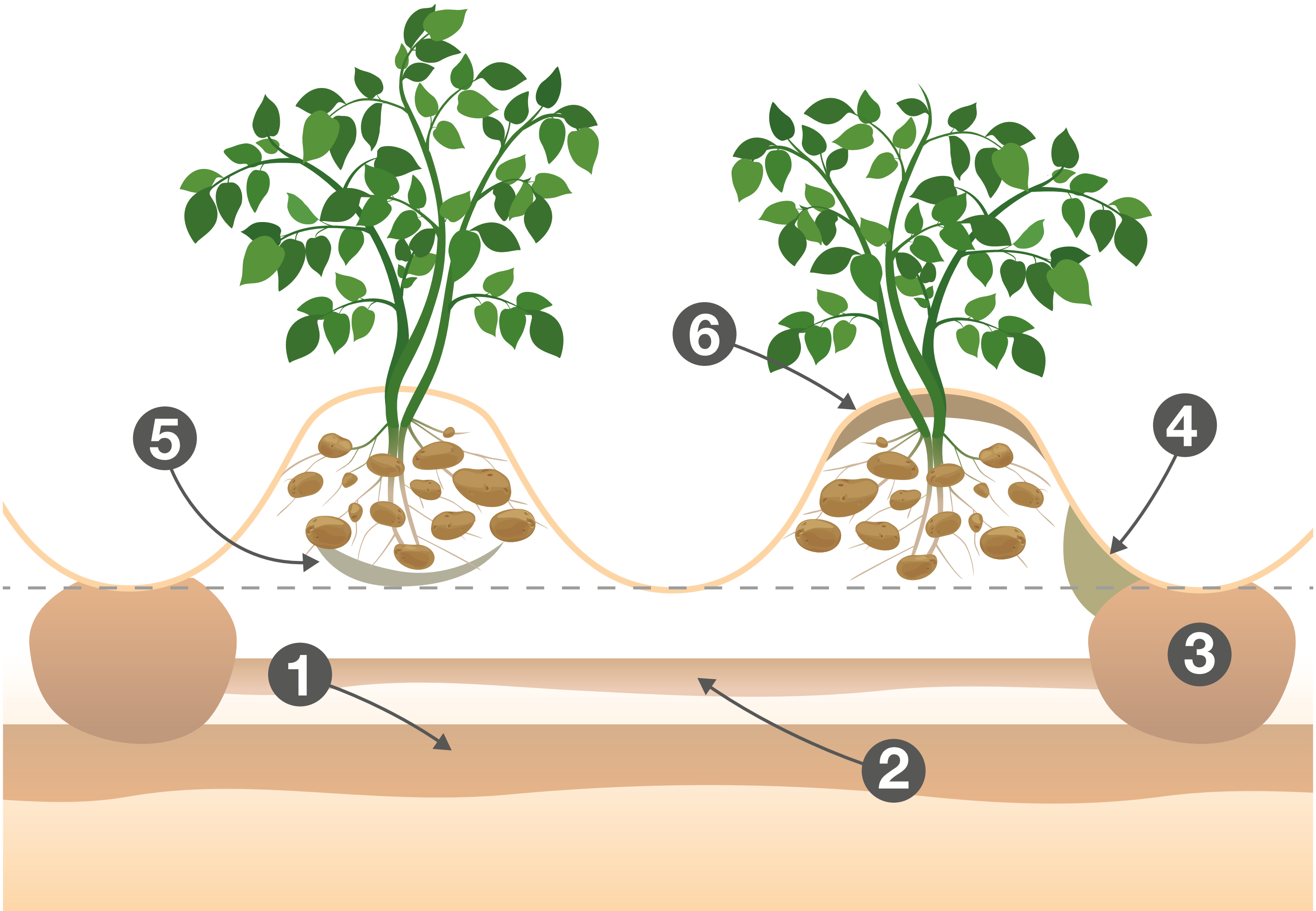


Figure 36. Common soil compaction zones in potato crops

To avoid compaction at these depths, work soils at appropriate soil moisture levels and minimise pressure on the soil (see Zone 2, above).

Zone 6

Compaction of the ridge ('capping') is caused by very fine soil particles that cement together and seal the ridge. It is more common in slumping-prone sands and silts. It often results in poor water infiltration and rooting. A lack of air can cause high seed death rates. Generally, coarser seedbeds give positive results and increase resilience to damage when planting. Avoid over-compressing wet soil with planter hoods.

Effective cultivation

For effective cultivation, remember:

- That soils and their moisture contents are highly variable (Figure 37). Therefore, use the information in this guide to judge cultivation depths
- To increase organic matter levels and grow roots through the profile
- To manage crop residues to reduce the need for management whenever possible during final cultivations. Appropriate autumn cultivations avoid undue pressure on wetter soils
- To integrate cover crops ahead of deeper primary tillage to make soil more friable and easier to cultivate. Establish cover early to allow sufficient growth. Destroy the crop late to help dry soil (but balance this with the need to manage residues)
- To irrigate carefully – irrigation can impose further pressure on soils
- To avoid excessively fine seedbeds

Key cultivation methods include:

Ploughing (with or without subsoiling) – Zone 1

Refer to the ploughing section. However, specifically note:

- The requirement for subsoiling along with ploughing
- Benefits of on-top (as opposed to in-furrow) ploughing
- Tyre pressure management (see trafficking section) is also key

When the surface zone is wet, use a plough to bring up drier soil by:

- 'Freshening up' slumped ploughing with tine cultivation. This can benefit bed forming in damper seasons or on soils with short cultivation windows
- Deep ridging (where used), which often brings a considerable quantity of wet raw material to the surface. This requires additional cultivations to break this down. Avoid deep operations in plastic soils

Less frequent ploughing can reduce organic matter loss. However, use rotational ploughing to manage weeds or to minimise the effect of residual herbicides

Subsoiling

For potatoes, subsoiling is a routine operation to ensure good drainage and root passage. According to research, two-thirds of commercial potato crops had compaction in the top 55 cm of soil that would stop root growth. The need for – and depth of – subsoiling should be carefully assessed (see the section on subsurface restructuring, including subsoiling).

Autumn subsoiling is effective for heavier soils, as conditions at depth are likely to be dry enough for shattering and overwinter slumping risk is low. Provided moisture levels are adequate, spring subsoiling reduces the risk of slumping on lighter, especially sandy, soils.

If subsoiling after planting, note that:

- Moisture conditions are not often suitable
- Unless high levels of compaction are found, the operation should be avoided
- Fragile sandy soils can benefit where compaction is present
- You should check the soil is dry enough at operation depth
- Stones can be lifted into the ridge
- Sinkage of vehicles, when spraying and harvesting, can occur because of loss of soil structural strength

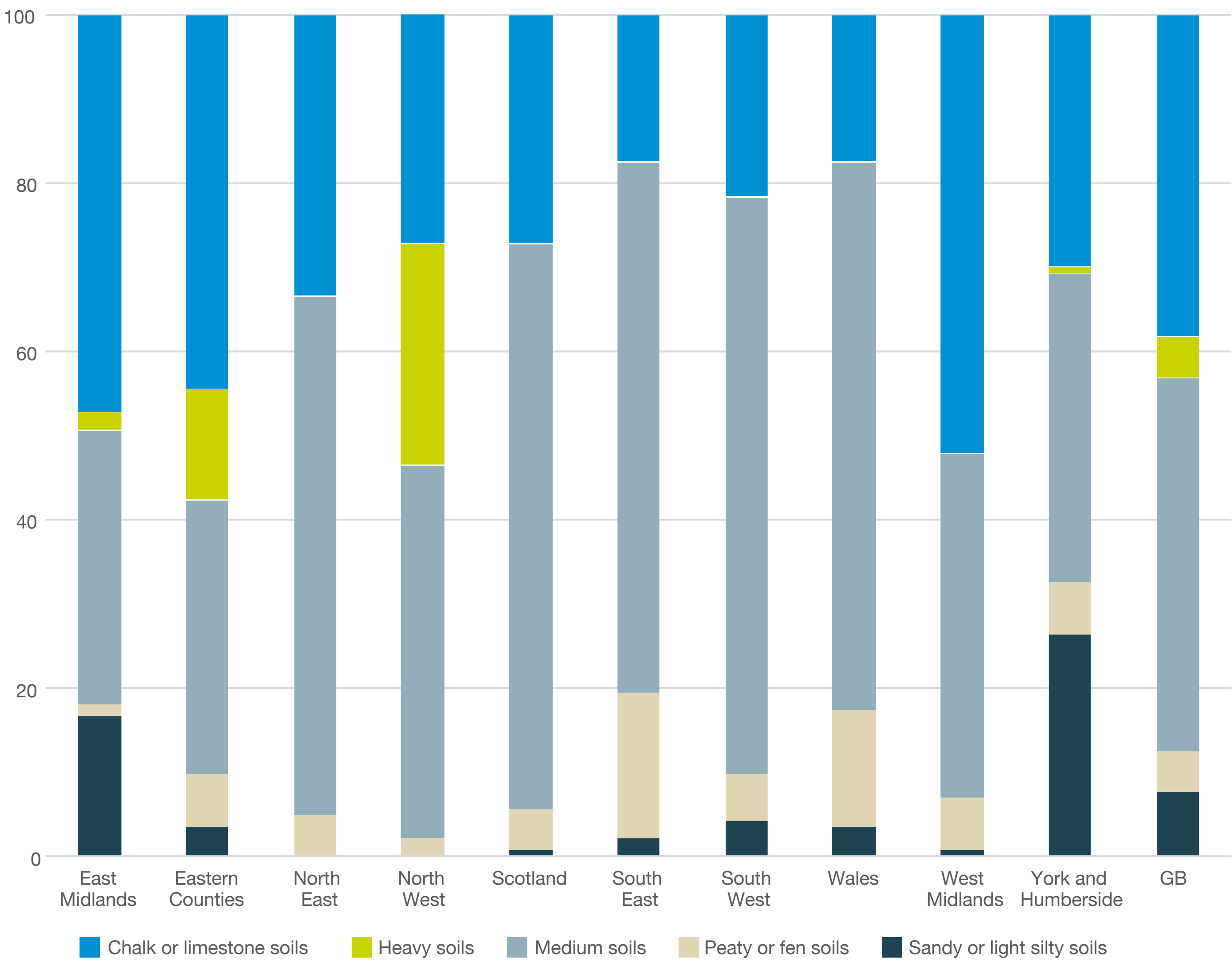


Figure 37. Breakdown of typical soil types on which potatoes are grown. Based on AHDB Potatoes voluntary Grower Panel Survey data (2005-19). Data do not reflect the total GB production area. Data that represent less than 1% of a soil type in any region are excluded from the results (included results are scaled up to 100%)

Non-inversion (as opposed to ploughing) – Zone 1

Non-inversion methods are suitable for soils with low organic matter content, especially loamy sands or silts prone to slumping. Retaining natural structure over winter for drainage, followed by deep non-inversion tillage just before bed-forming and other operations, can lead to better structural resilience.

If power is available, it is sometimes possible to combine the primary pass and deep ridging/bed-forming, or to combine bed-tilling and separation into a single (Tillerstar) operation into stubbles on slump-prone soils. Note that:

- A combined subsoiling and non-inversion mixing action can be more efficient and less damaging than a plough-based system, if fewer passes are made overall
- One deep pass or two progressive passes to maximum cultivation depth can be made

For general guidance, see the deep non-inversion tillage section

Potatoes: secondary bed tillage and destoning

General information – Zones 2, 3 and 4

- Aim to achieve 5–8 cm of loose soil below the bottom of the planted seed tuber. This may be difficult to achieve in wet soils
- Avoid operating at the same depth with multiple operations to minimise planes of weakness that create barriers to water and root movement
- Towing tractors frequently create damage – minimise pressures and tyre slip/draft effects, especially on loose, cultivated soil

Bed forming – Zones 2 and 3

- On suitable high clay content soils, where soil moisture conditions are appropriate, autumn bed-forming can allow natural weathering
- Dry conditions at bed-forming and low winter rainfall are key
- Generally, spring operations have a small window for optimum soil moisture
- It is vital to avoid operations at depths that are deeper than necessary, or wet soil will be compacted into zones of clods or smeared layers
- Match bed-forming depth with destoning depth. Excess clod formation can occur where beds are very deep and the destoner tractor can push soil off the top of the ridge and into the furrow
- Bed-forming deeper than the critical depth (when upwards lifting changes to sideways or downwards smearing) in spring can also produce excessive numbers of clods that need to be removed by bed-tilling or more aggressive destoning

Bed-tilling – Zones 2 and 3

- Blade type influences the likelihood of structure damage and tilth quality. The results are also determined by soil moisture, forward speed and degree of blade wear. Rake angles are critical and wear can increase these
- Low rake angles lift and loosen, high rake angles compact and smear
- Considerably increased rooting resistance following bed-tiller tines can occur when L-shaped blades are used
- Less resistance occurs when pick, angled and spike blade tines are used (Figure 39)

Figure 38. Bed-forming (left) and bed-tilling (right)

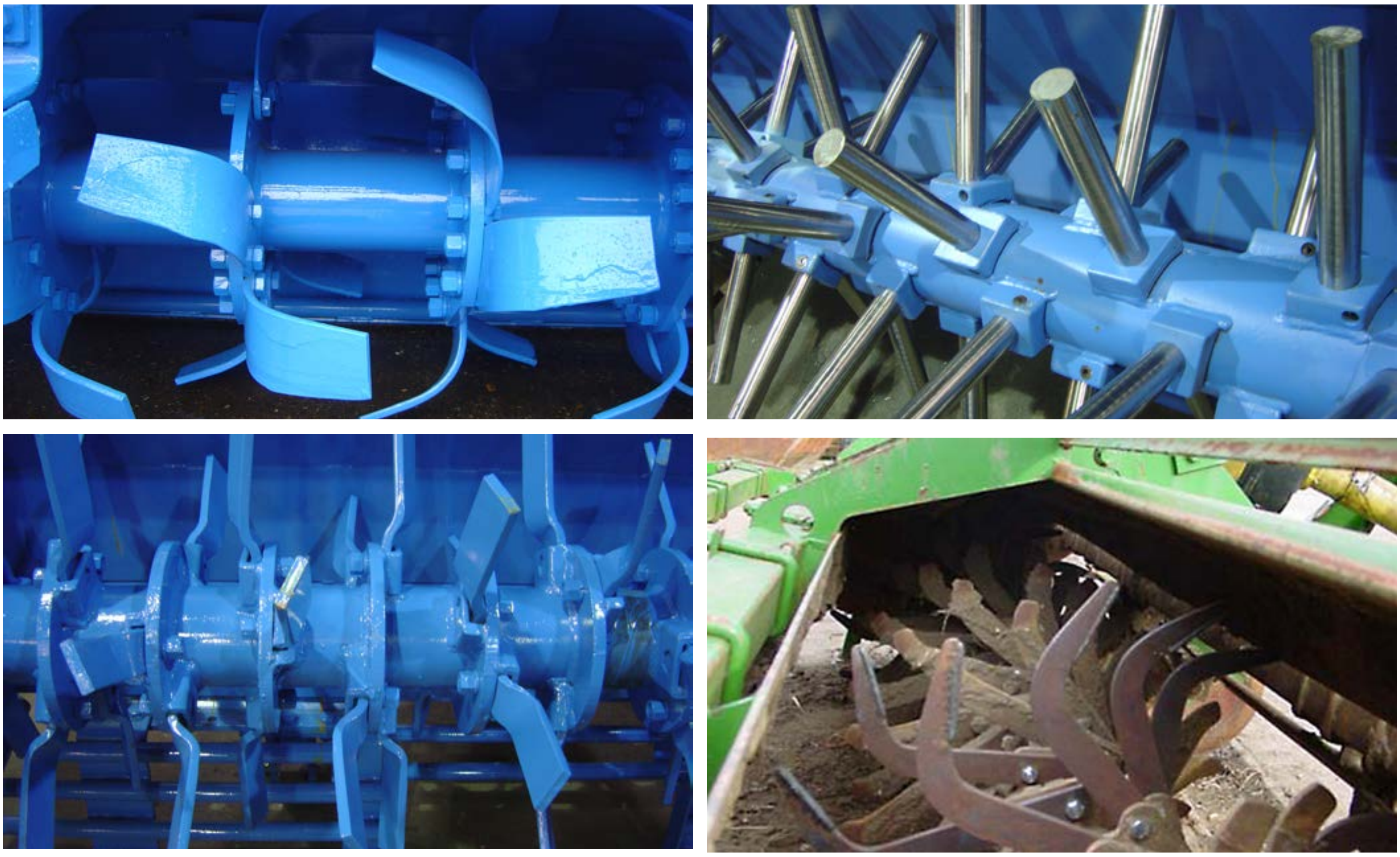


Figure 39. Types of tiller blades: L-shaped (top left), spiked (top right), angled, (bottom left), pick tines (bottom right)

- Replacing bed-forming and destoning with one operation can save money and optimise output on slump-prone soils. It can also save the need to plough
- Work when moisture levels at the furrow/bed base and ridge sides are dry enough to minimise smearing and clod formation
- Avoid overcultivating by bed-tilling only:
  - the parts of the field that require it
  - the uppermost half of the bed, where most clods are situated. This speeds progress considerably, saves fuel, improves clod breakdown and avoids creating overly fine seedbeds
- Use tines to remove thin compacted layers at the rotor working depth. These can be fitted to a bed-former and aligned to the final planted rows (Figure 40). Only do this if working shallower at a drier level does not solve the problem
- Careful setting of eradicator tines will help remove bed-tiller (and planter) tractor compaction. Prevention (managing ground pressures) is preferable to cure and makes curative actions more effective
- A minimised working depth will save power, fuel and, more crucially, increases work rate. Start shallow and increase only as required
- A separator web with a wide pitch (such webs being more ideal for stony soils) or increasing the spacing set between separator stars produces coarser, more stable soil aggregates and reduces slumping

Destoning – Zones 2 and 3

- Do not cultivate deeper than is necessary
- Destoning (Figure 41) should not occur at depths deeper than 35 cm on sandy soils or 28 cm on heavy soils
- Identify the critical depth for destoning and work above this depth. The critical depth can be found by gradually increasing working depth (from a shallow start) and observing a notable increase in separated soil. Working at or deeper than this setting is inefficient and damages the structure beneath. In all cases, check the discharge – there should be no usable soil in the furrow base
- Shallow destoning permits 20–40% faster work rates. It provides greater opportunity for soils to be cultivated when closer to their optimum moisture content
- Shallower destoning reduces machinery wear, results in lower repair and depreciation costs and decreases breakdown risk
- Seedbeds can be made appreciably coarser and shallower before any increased risk of common scab or greening

Wheeling management – Zones 3 and 4

- Wheeling management machines, such as tied ridger, indenting or profiling rollers with shallow angled tines, can reduce water movement down wheelings more effectively than subsoiling (Figure 42)

Figure 40. Option to loosen below the pick tines of a bed-former, aligned to the rows that will be planted next

Figure 41. When destoning, monitor depth for improved work rates and fuel consumption

Figure 42. Profiled and tied ridges hold water from running downslope

Establishment approach assessment tool

A change in cultivation approach does not necessarily mean going from one extreme to the other. Tillage operations cover varying degrees of soil movement, from relatively little disturbance to complete inversion.

Use this tool to consider the soil management factors and their importance to your unique farming situation. The scores produced are for guidance only. Use them to identify where improvements could be made across your farming system. Where possible, adapt management to achieve higher scores.

A managed approach means that you can adapt your cultivations (as required) on a rotational basis, basing your decision on soil/weather conditions, previous cropping, weed burden and soil assessments. A managed approach has been shown to result in more consistent yields and greater gross margins over the longer term.

The most appropriate establishment option depends on many other factors (for example, machinery availability).

Before considering reduced cultivations:

- Determine if the soil type is suitable
- Do your research: visit other farms using reduced tillage
- Start with fields where soil structure and drainage are in a good state
- Assess how often reduced cultivations may have been appropriate over recent seasons
- Carefully assess whether soil and weather conditions are suitable each season
- Be flexible: change back, if conditions dictate
- Manage trafficking and ground pressures: minimise the impact of heavy equipment
- Ideally, carry out all cultivations on friable, workable soil
- Soil-loosen, if necessary. Grow roots through the soil, whenever possible, to stabilise structure
- Assess current system and equipment needs compared to those needed for reduced cultivations
- Change to a new system in a planned manner. Soil type will often choose your system for you
- Consider machinery-sharing, contracting or trading in some existing machinery to fund reinvestment

How to use the tool

Either use the paper-based tool (on page 31) or the online tool at **ahdb.org.uk/arablesoils**.

For each of the factors, select a score (range 1–10) and enter it into the appropriate 'score choice' cell.

Note: Although some scores are defined (blue cells), any score (range 1–10) can be selected.

Total score – establishment options: combinable crops/leys

<60	Varied approach required, with occasional inversion tillage
60–70	Aim to reduce tillage (option to strip-till possible)
>70	Aim to significantly reduce tillage (option to direct drill, when appropriate)

Total score – establishment options: potato, root and field vegetable crops

<55	Conventional approach often required, but varied in response to season/conditions
55–65	Aim to reduce tillage (intensity) and depths for subsoiling, ploughing, bed tillage and separation depth
>65	Aim to reduce tillage (operations and intensity) and depths for subsoiling, ploughing, bed tillage, separation depth and declodding

Page	Factor	Factor score choices										Score choice
4	**Rainfall**	Annual rainfall >1250 mm		Annual rainfall 1250–950 mm			Annual rainfall 950–650 mm			Annual rainfall <650 mm		
	Score	1	2	3	4	5	6	7	8	9	10	
4	**Soil type**	Slumping-prone sands and silts			Soil varied; some non-structuring			Heavy soil; self-structuring			Light/medium soil; self-structuring	
	Score	1	2		4	5		7	8		10	
4	**Management (time available)**	Prescriptive/ little time			Prescriptive/ some time			Flexible/little time			Flexible/ good time	
	Score	1			4			7			10	
4	**Drainage**	Drainage issues common		Some drainage issues			Well drained, low permeability			Freely drained, permeable		
	Score	1	2	3	4	5	6	7	8	9	10	
5	**Residues/ organic matter**	Residues removed and no organic matter returned			Residues removed and FYM or other organic amendments returned		Some residues removed, no organic matter returned			All residues remain and are well-managed; FYM or other organic amendments also returned		
	Score	1	2		4	5	6	7		9	10	
6	**Cover/ catch crop**	Not used			Experimenting				Some used		Widespread use	
	Score	1			4				8		10	
7	**Trafficking policy**	No controlled traffic farming High-pressure tyres used					No controlled traffic farming Low-pressure tyres used		Some controlled traffic farming Low-pressure tyres used		Fully controlled traffic farming Low-pressure tyres used	
	Score	1					6		8		10	
9	**Irrigation**		Regular irrigation								No irrigation	
	Score		2								10	
10	**Weeds**	High pressure (annual meadow grass, rye-grass and brome)		High black-grass pressure				Borderline manageable		Manageable with rotations		
	Score	1	2	3	4			7		9	10	
10	**Pests**	General pest risk			Slug risk high			Slugs manageable			Slugs controlled	
	Score	1			4			7			10	
Total score												

Summary of cultivation approaches for combinable crops

Plough (inversion)

Summary

- **Viewed as a ‘conventional’ cultivation**
- **Inversion and burial of surface residues**
- **Plough depths vary (15–40 cm)**
- **Typical depths are 20 cm and 40 cm**
- **Subsequent cultivation passes are often used to condition the soil**

Pros

- Gives a residue-free surface and a ‘clean start’
- Buries weed seeds below emergence depth
- Enhances biological breakdown of residual herbicides
- Loosens compaction down to plough depth
- Mineralises nutrients for availability in the following crop
- Option of pressing (flexibility to suit conditions)
- Capable of operation in wetter conditions than other systems

Cons

- The residue-free surface can be prone to slumping
- Can return buried weed seeds, if ploughing is frequent
- Oxidises organic matter, which reduces soil resilience
- High soil disturbance destroys natural supportive structure
- Risk of mineralised nutrients being lost to the atmosphere
- Pressed soil can slump and loose soil can lose moisture
- High cost, low output (relative to some other options)

Deep non-inversion

Summary

- **Deep soil movement**
- **Typical depths are 20–35 cm**
- **Crop residues mixed into the top soil. Usually, moved to depth, unless low surface disturbance loosening is used in combination with shallow surface mixing**

Pros

- Retains the natural soil profile (surface tilth and subsurface structure)
- Removes subsurface compaction
- Enhances biological breakdown of residual herbicides
- Mineralises nutrients for availability in the following crop
- Pressing as part of the operation gives a weatherproof finish
- Often lower cost than ploughing, if all operations are accounted for
- Combined deep and shallow operations in one pass

Cons

- Relatively high soil movement can compromise structure resilience
- Mixes weed seeds through the profile (uncontrolled emergence can result)
- Some risk of mineralised nutrients being lost to the atmosphere
- Can leave a firm surface prone to slumping
- High cost compared to less intrusive systems
- Less flexibility, if deep tillage is not required on some areas
- Usually reliant on rotations and/or chemicals for weed control

Shallow non-inversion

Summary

- **Shallow surface movement**
- **Typical depths are 5–10 cm**
- **Most crop residues remain on the soil surface**
- **Can be combined with low surface disturbance loosening (as a separate operation)**
- **Uses discs or tines**

Pros

- Retains the natural soil profile (surface tilth and subsurface structure)
- Leaves residues on or near the surface shallow mixed (stale seedbed)
- Associated control of slugs by shallow tillage and consolidation
- Pressing as part of the operation gives a weatherproof finish
- Low cost, high output
- Removes compaction, if combined with low-disturbance loosening

Cons

- Needs a well-structured subsurface to prevent barriers
- Disc-based option good in residues. Tine-based action can block – requires adequate tine clearance
- Disc-based option can smear in damp conditions
- The above can imply compromise, depending on conditions and season
- Needs a drill capable of operating in high residues
- If combined with loosening, more passes are required
- Often reliant on rotations and/or chemicals for weed control

Strip tillage (non-inversion)

Summary

- **Combines tillage (typical depths are 5–10 cm) and drilling, if needed, in strips* (as opposed to the entire field)**
- **Specialist drill having leading cultivation elements**
- **Most crop residues remain on the soil surface**
- ***Can be considered a form of direct drilling**

Pros

- Combines the soil-drying and warming benefits of conventional cultivations with the soil-protecting advantages of no-till
- Works on a proportion of the field (reduces overall soil movement)
- Increased efficiency, while allowing tillage (as required)
- Retains undisturbed soil columns to support traffic and drainage
- Can be split into cultivation and drilling, in some cases, for flexibility
- Option to place fertiliser in drilling zone can save input costs
- Can provide a stepping stone to no-till or direct drilling
- Potential for companion cropping between strips

Cons

- Different surface conditions/residue levels can increase threats of slugs and carry-over of certain diseases
- Gives different surface conditions for weed and pest control measures
- Higher draft than shallow tillage (although less than full-width tillage)
- Care required to avoid throwing disturbed soil on uncultivated strips (limit speeds)
- Can be limited for deeper operation (e.g. in high moisture situations)
- Higher levels of residues imply zone placement of fertiliser is needed
- Residue manager options can be required to give clear drilling zones
- Often reliant on rotations and/or chemicals for weed control

Direct drilling (non-inversion)

Summary

- **Crop established in one pass, direct into land without prior cultivation**
- **The operation often uses some form of cultivation (e.g. to loosen topsoil before seed placement), followed by rollers to firm the soil**
- **Typical depth is 5 cm. Where no soil movement occurs, it is 'no-tilled'**
- **Uses either a specialist drill or a cultivator drill combined with loosening tines**

Pros

- A single pass system with flexibility for some cultivation
- Allows appropriate mix of tillage and drilling on soils needing both
- Low cost of operation (other than capital outlay)
- Reasonable/high output
- Low disturbance for weed management and, as needed, some structuring
- Over time, soil structure and biological activity improves

Cons

- Needs effective residue management and, ideally, good soil structure
- Ideally, needs tilth to be present for the following crop
- Specialist kit, although can be based around a cultivator drill
- Residue manager (row sweep) options can be required to give clear drilling zones
- Higher levels of residues combined with minimal soil disturbance imply zone placement of fertiliser can be needed
- Allow for restructuring, if needed, even as a separate pass
- Generally reliant on rotations and/or chemicals for weed control

No-till/zero-till (non-inversion)

Summary

- **Crop sown directly into previous crop's stubble without any prior topsoil loosening**
- **Specialist operation that often uses a disc to cut a slot in the soil, in which the seed (and fertiliser) is placed. Following press wheel(s) close the slot**
- **Sometimes referred to as direct drilling**

Pros

- A single pass system that requires adequate structure (tilth and subsurface)
- Reduced overall costs (fuel and machinery)
- No other operations – simple to manage in suitable conditions
- Soil structure and biological activity gradually improves (especially earthworm numbers)
- Successfully used by some farmers on appropriate soils
- Opportunity to increase area of autumn-sown crops
- High work rates and area capability
- Drilling phased to take advantage of favourable weather conditions
- Stones not brought to the surface
- No compaction below plough furrow
- Reduced erosion, run-off and loss of particulate P
- Better retention of soil moisture in dry areas

Cons

- Needs effective residue management and good soil structure
- Usually needs a specialist, high-cost kit
- Can require careful residue management when drilling (row sweeps)
- All tilth needed for the following crop needs to be naturally made
- Needs good weather and, often, patience to create good tilth. Can impose high demand on management where soils are variable
- Drill slot closure can be problematic in certain soils and moisture levels
- High levels of surface residues imply a disc is needed somewhere
- Higher levels of residues combined with minimal soil disturbance imply zone placement of fertiliser is needed
- Generally reliant on rotations and/or chemicals for weed control
- Unsuited to poorly drained or poorly structured soils, especially sandy or high silt content soils
- Increased variability of crop yields, especially in wet seasons
- Crop establishment problems during very wet or very dry spells
- Increased grass weed control problems and heavy reliance on herbicides
- Increased slug damage
- Increased risk of topsoil compaction
- Problems with eradicating residual plough pans
- Risks of increased nitrous oxide (N_2O) emissions and leaching of dissolved reactive P
- Unsuited to incorporation of solid animal manures
- Increased risk of fusarium deoxynivalenol (DON) mycotoxins

Further reading

Our website is a gateway to all of our soil-related activity. The pages provide practical solutions and an insight into our research investment.

ahdb.org.uk/soil-principles

ahdb.org.uk/greatsoils

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Produced for you by:

AHDB
Stoneleigh Park
Kenilworth
Warwickshire
CV8 2TL

T 024 7669 2051
E comms@ahdb.org.uk
W ahdb.org.uk
@TheAHDB

If you no longer wish to receive this information, please email us on **comms@ahdb.org.uk**

70027 0223