POTATO COUNCIL

Soil management for potatoes

Updated 2013

Introduction

Soil is the farmer's key asset. Improving your soil will provide clear benefits to your business and the environment. Recognise and address the limitations of your soil and you can unlock its potential. Understand your soil and you can reduce the risks and costs of soil damage, water run-off and erosion.

But today's tractor driver sits remote from the soil. A high horse-power tractor is capable of tilling beyond previous physical limits, putting both soil and plant health at risk. Growers and operators need to be aware of the significance of soil conditions during soil preparation and planting. Good soil management can deliver maximum productivity from the current crop, and for years to come. It goes beyond merely meeting the standards required for cross compliance.

This guide provides a greater understanding of the principles of practical soil management. Use it to help examine and understand your soil, the threats it faces and the fundamentals that can help achieve optimum returns from your potato production system.

Threats to Soils

Loss of soil structure. Poor timing of activities and overworking of soil may lead to slumping, capping and compaction. These problems can reduce soil aeration, the volume of soil explored by roots, and the water available to them. Foliage and tuber growth suffer as a result. Structural problems reduce water infiltration and encourage water run-off. This leads to soil erosion, crop damage, flooding and watercourse pollution. Reduced organic matter, long steep slopes and poor crop cover increase the risk.

Climate change. Heavier rain events result in waterlogged fields. Drier summers increase the need for irrigation. Dealing with these effects may mean increased drainage need and more soil erosion.

Contamination. Brown water leaving a field is a sign that soil, pesticides and nutrients are washing off your land. Where this occurs it increases the cost of treating water for human consumption and can cause environmental damage and loss of biodiversity.

Soils face a number of threats that limit their ability to perform:

- Compaction
- Loss of organic matter
- Contamination
- Erosion
- Climate change
- Loss of biodiversity

These problems interact. Together or individually they affect crop growth, yield and tuber quality and hamper field machinery operations.

"The soil must be man's most treasured possession; so he who tends the soil wisely and with care is assuredly the foremost among men."

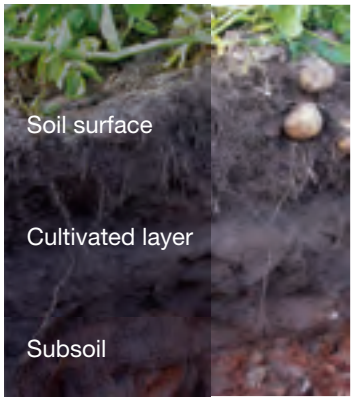
Sir George Stapleton

Contents

1 Soil assessment

Soil profile

You can learn a lot from studying the soil profile. Choose where to dig carefully, prepare the profile, then examine each layer of soil.



Look at the root growth. The pattern of roots in the growing crop can be used as an indication of any suspect layer in the soil. Look at the position, quantity and vigour of roots in the subsoil – they show up the effects of many soil properties. The dryness of zones in the soil may also shed light on root activity.

Potatoes are particularly sensitive to compaction. Severe panning may show as a web of roots on the upper surface of the pan with only a few penetrating below.

Texture and structure

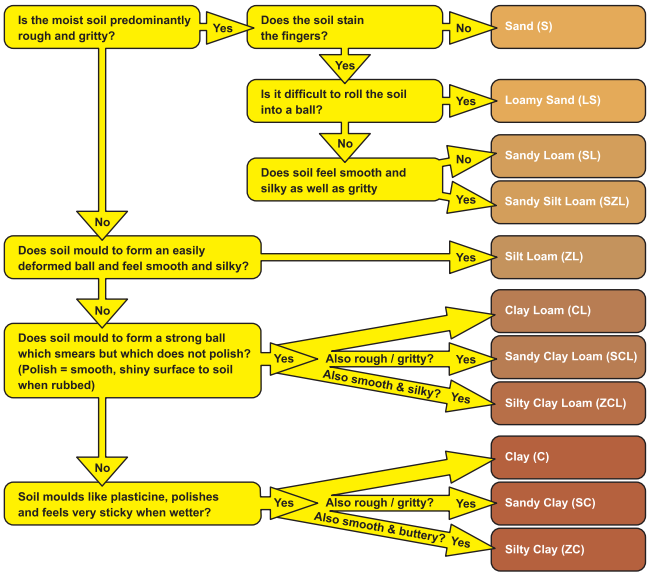
Texture – the relative amounts of the primary particles sand, silt, clay and organic matter.
Structure – the arrangement and packing of particles resulting in their grouping into aggregates.

Soil texture is fixed, while soil structure is changed by many agricultural activities including cultivation and machinery traffic.

Texture

A soil's texture determines almost all aspects of soil behaviour, including use of certain herbicides, drainage characteristics, porosity, cultivation needs and available water reserves.

Marked changes in texture can occur within a vertical soil profile. These can have a considerable influence on water movement and root growth.



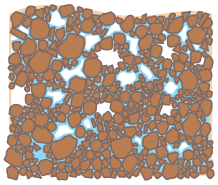
Structure

Soil structure is the architecture of the soil and describes the size, shape and stability of units in which the individual particles of the soil are held together. The only opportunity for growers to modify soil structure is the period between crops. The effect on structure depends on the nature of cultivation and state of the soil.

A hardened layer can form in the subsoil where quantities of calcium carbonate, silica or iron, manganese and aluminium compounds cause particles to bind together tightly in a discrete layer. They are usually linked to a fluctuating water table.

Aggregates – individual mineral particles of the soil are held together.
Pores – spaces between the aggregates that play a key role in good soil husbandry.
Bonds – organic matter, clay and, in some soils, calcium and iron compounds that bind the larger particles together. The strength of the bonds determines the stability of the soil and its potential to withstand wind and water erosion.

Porosity



Pores are essential to the dynamics of the soil profile as they allow movement of water, air and nutrients within the soil.

The role of air spaces

Healthy crop roots and beneficial soil organisms need oxygen. Low oxygen concentration in the soil slows root function, tuber development and skin set. This can prolong the period of susceptibility to surface diseases such as powdery scab and black dot.

Large pores, called **macropores**, allow the free movement of water and air. In sandy soils they can be the spaces between grains. In other textures they are usually cracks and fissures between soil structures and worm or old root channels. Such pores are very prone to closure by compaction. Water movement out of soils replenishes the soil gas environment.

How water affects structure

As it gets wetter, soil becomes softer and is more easily deformed and will reach a phase called plastic. Above its plastic limit a soil that is compressed, through mechanical

Severe damage can result from travelling on or working soils that are excessively wet

cultivations for example, will retain the compressed form. The greatest risk of structural damage occurs when a soil is at or near field capacity (see soil water status conditions on page 6).

How cultivations affect structure

The mechanical mixing of the soil compacts and shears aggregates, fills pore spaces and speeds up the decay and oxidation of organic matter. The amount of damage caused depends both on the type and force of cultivation and the conditions of the soil – whether wet or dry, hard, soft or loose. A feature of this is that over-worked soils can be more prone to slumping and capping, particularly if the soil has high silt content. Continued cultivation and wheel traffic also causes compaction.

Over-working a soil can damage its structure. Consider ways to reduce cultivations

Further Reading

There are several good guides to examining soils such as *A Guide to Better Soil Structure* (NSRI, Cranfield) and *Visual Soil Assessment* (SMI/Vaderstad).

The problem for arable soils

There is concern that intensive arable farming is causing the Soil Organic Matter (SOM) content of soils to fall to unacceptable levels. SOM plays an important, yet often poorly understood role in sustaining soil functions.

Long-term arable soil contains less organic matter than adjacent grassland soil. Arable total SOM content is difficult to increase and there is no easy way to measure any change. But soil loss from erosion does decrease markedly as SOM content increases.

Soil organic matter (SOM)

What organic matter does

- Holds soil particles together, reducing erosion
- Improves structure, making the soil more friable and easier to work
- Helps maintain an open structure, aiding root growth and penetration
- Increases porosity for air and water infiltration, reducing run-off
- Stores and supplies nutrients
- Retains carbon from the atmosphere and other sources
- Provides a food source for soil microbes

The benefits growers notice from SOM

- **Cultivation:** Easier cultivation (faster forward speeds, less implement wear), less subsoiling needed, easier to produce a suitable tilth for planting, more flexibility in or greater window of opportunity for mechanical operations
- **Soil structure:** Better moisture retention, less capping, improved tilth, less susceptibility to compaction and erosion
- **Soil biota (life):** Increased earthworm and insect activity
- **Fertiliser:** Less inorganic fertiliser needed to optimise yield
- **Drought resistance:** Yield affected less in drought years, lower irrigation requirement

Importance of SOM

There's growing evidence that suggests the 'active' fraction of SOM – up to 10% of the total SOM – is more important to soil physical properties than total SOM. This consists mainly of recent additions of crop residues and organic manures. Under arable cropping, annual returns of crop residues to the soil are the major source of these active substances.

Compost

The UK potato industry is a potentially large market that could benefit from quality composts, with potatoes planted on 121,800ha of agricultural land in the UK in 2012. If compost was applied to a quarter of this area at an application rate of 30t/ha, just under a million tonnes of quality organic matter would be beneficially recycled.

Compost should be applied prior to potato planting and incorporated into the soil. It is recommended that PAS (Publicly Available Specification) 100 composts are used for potato production for the benefits to the soil, crop and the environment. These benefits include:

- Enhancing water retention
- Improving heavy land
- Reducing compaction
- Reducing production costs
- Supplying nutrients, especially P and K

Soil water movement

Soil is constantly wetting and drying throughout the layers of its profile. These are rarely at the same soil moisture state, and much depends on texture – water moves relatively slowly through clay soils, or clay layers in a soil, and through compacted layers. This means the topsoil may hold water that exceeds its plastic limit before drains start to run, and the soil is prone to damage.

The three soil water status conditions

Saturation
All the pores are filled with water and there is no air in the soil. Potatoes are highly sensitive to waterlogging. Damage includes Blackheart, erupted lenticels and plants may die. Roots will be affected after even a short time, leading to premature root death and crop senescence.

Field capacity
Reached when a soil has drained for about 48 hours following heavy rain, air has re-entered the soil and no more water is lost through gravitational drainage. Soils usually change from being at field capacity or greater during winter to being in soil moisture deficit in summer.

Permanent wilting point
Soil dries progressively until only the smallest pores contain water. Roots are unable to draw on this causing leaves to wilt. Plants may recover at night, but when damage is permanent, the soil has dried to the permanent wilting point.

Generally soils with larger pores, such as sands, will drain more quickly and retain less water. However if water running through the profile encounters a layer of coarse material, it often stops until the soil above it becomes nearly saturated. This is because the water cannot enter the sand layer until the large pores can pull water into it. So a soil that becomes sandier with depth holds more water than its texture would suggest.

Capillary action is responsible for moving water from wet areas of the soil to dry areas. It describes the attraction of water molecules to soil particles. Smaller pores pull water towards the centre of the pore with more force than larger pores, rather like small or large tubes. It is easy to remove water from larger tubes, but it takes a lot of suction to remove water from the smallest tubes. So a plant must exert considerable suction to remove water from small pores in the soil.

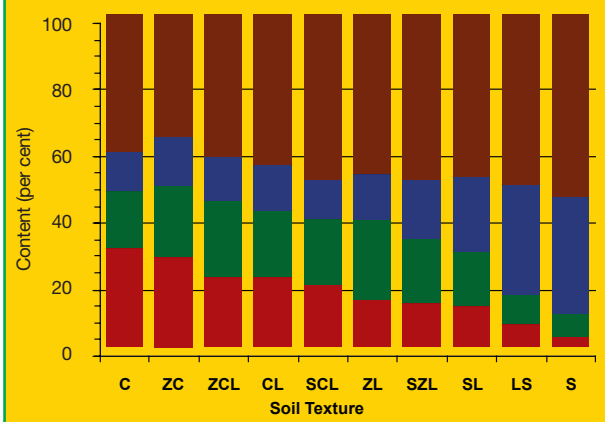
Hydraulic conductivity describes how easily water can move through the soil. It depends on the permeability of the soil (pore size, fissures and compaction) and the moisture content of the soil. The infiltration rate can only be maintained if the system of coarse pores is maintained. The zone where this system is most likely to collapse is the soil surface. Wet soil aggregates are weak and can easily be broken by the impact of rain drops. This causes soil particles to become detached and block the coarser surface pores.

Infiltration is the process by which water on the ground surface enters the soil. Large cracks and macropores allow a rapid infiltration. Smaller pores take longer to fill and rely on capillary forces as well as gravity.

Drainage rates are a combination of hydraulic conductivity and infiltration. In most soils, the subsoil drainage rate will control the whole profile.

The availability of water to potato roots

The moisture content of a soil between field capacity and permanent wilting point is available to crops and is known as the **Available Water Capacity** (AWC). If more water is removed by evaporation and plant transpiration (evapotranspiration) than added through rainfall or irrigation then soil moisture content reduces creating a **soil moisture deficit** (SMD). Potato crops are sensitive to relatively low levels of water stress and it is important to keep the soil moisture deficit below a threshold that could limit growth. A large component of increased sensitivity to water stress in potatoes is the lack of accessibility to soil water owing to the inability to root in even moderately compacted soils.

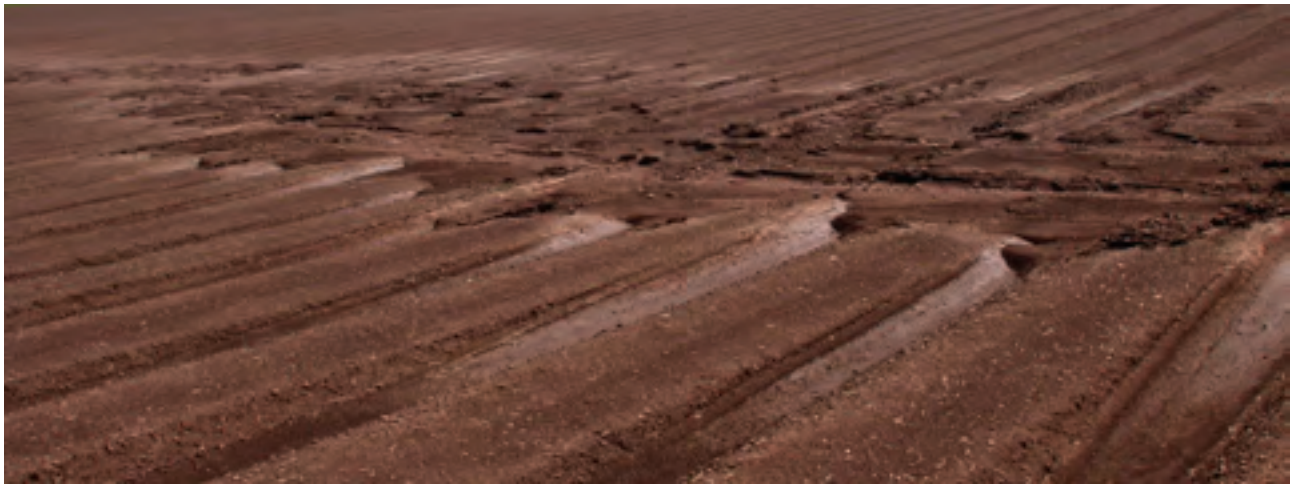


Knowing the water content of the soil alone is not enough, for example if the soil is at 29% water content then:

- Sand is wetter than field capacity and drainage will still be taking place
- Sandy silt loam is in an ideal condition for plant growth
- Clay is at permanent wilting point.

C = Clay
ZC = Silty clay
ZCL = Siltly clay loam
CL = Clay loam
SCL = Sandy clay loam
ZL = Silt loam
SZL = Sandy silt loam
SL = Sandy loam
LS = Loamy sand
S = Sand

2 Soil-related problems



Erosion

Wind and water are the weather-related factors that cause soil to erode. Soil erosion is the relocation and movement of soil within fields and into other parts of the landscape including roads, buildings, streams and rivers.

Light sands and peaty soils are mainly affected by wind erosion. Water erosion occurs on all soils but is most dramatic on unstable sands and silts.

Soil erosion problems

- Loss of fertile topsoil
- Systematic reduction in overall soil quality
- Reduction in agricultural productivity
- Loss of important nutrients, in particular phosphorus
- Eroded soil particles become sediment particles, moving from land towards river systems to spoil fish spawning grounds
- Affects other people – soil on road, or blocking streams and drains
- Destruction of wildlife habitats and wildlife
- Pollution
- Potential legal action

Wind erosion

Some of the most common soils for growing potatoes are those most likely to suffer – the non-cohesive sands (where individual particles are only weakly, if at all, held together), light loams and peats. On these soils, if you are growing crops such as sugar beet and fine-seeded vegetables, erosion is more likely to take place. But flattening of potato ridges can occur.

The lighter and less dense the particles, the more they are likely to erode. So fine sands or relatively large particles on peaty soils (around 1mm) are most likely to be lifted by the wind. Increasing organic matter helps bind sand particles.

Damage

- Young foliage sand-blasted
- Potato ridges flattened, exposing tubers
- Crops smothered by deposited soil
- Ditches filled in
- Dune-like appearance on roads

How to reduce wind erosion

- Establish windbreaks (e.g. hedges, lines of trees) but this may take many years and they are only effective over short distances
- Create a vegetative cover, surface trash or leave a rough soil surface
- Align potato ridges across the normal wind direction
- Fleece or polythene covers give very good short term cover
- Increase soil organic matter content through applying slurry or manure (check NVZ rules and crop requirements)
- Increase the cohesiveness of the soil particles by using soil stickers
- Dampen the soil using irrigation

2 Soil-related problems


Source: Highways Agency

Water erosion

Water erosion is a natural process that removes topsoil. When soil loss exceeds regeneration of soil by weathering, soil fertility decreases and crop yields are reduced.

Water erosion facts

- Land that floods is susceptible to erosion and run-off, particularly when under cultivation
- Areas that flood at least one year in three should not be cultivated for potatoes.
- Since the 1970s it has increased
- The rise in winter cereal acreage is a contributory factor
- More intensive cultivations have reduced structural stability
- Research at Silsoe College has recorded losses up to 4.5kg per sqm on sandy loam soils
- Soil renewal is at best only 0.1kg per sqm per year
- A soil loss of 1mm over 1ha is equivalent to 11-16 tonnes

Soil erosion is most likely to occur in winter and spring, when soils are saturated. Potatoes are very vulnerable just after planting, and irrigation can compound the problem, as growers try to keep the field close to field capacity for common scab control. On sloping sites water will run off, carrying soil particles with it.

Factors that determine extent of run-off and resulting damage

- Soil texture – sands, silts and those with a low SOM are vulnerable
- Soil compaction – pans and compacted areas limit infiltration

- Vegetation cover stabilises the soil
- Tillage lines and wheelings
  - Consider running a tine through to improve infiltration
  - Break up long runs with buffer zones (either cultivated or grass strips)
- Slope characteristics – break up long slopes and consider taking steep areas out of cultivation

The signs of erosion and run-off

Rain or irrigation that falls at a rate faster than the soil can absorb it will form surface water-ponding and run-off. This can occur where capping or compaction is present. If the water flow increases or speeds up, shallow channels (rills) may be formed. Additional water volumes will turn the rills into deeper gullies. Any evidence of rilling should be taken as an indication that significant erosion is occurring.


Source: Cranfield University

During run-off, soil particles of all sizes may be moved. When flow is checked, these start to settle. Stones and gravel settle out first, followed by sand, which can commonly be seen as depositional fans where rills run onto level or vegetated ground. Silt-sized particles, and especially clay-sized particles and organic matter, stay suspended much longer, and can more readily reach drains and watercourses. Every time a local stream or ditch is seen running brown it is as a result of soil erosion.

The unseen effects

Small deposits of coarse sand at the foot of a field should not give false reassurance that the eroded soil has stayed within the field. The fine material, together with nutrients and pesticides will have travelled much farther. Where they finish up depends on the farm and landscape features, such as roads and tracks, and natural slopes.

The erosive power of rain will be reduced if the soil surface is covered by a growing crop (stubble or trash after cereals).

2 Soil-related problems

Diffuse pollution

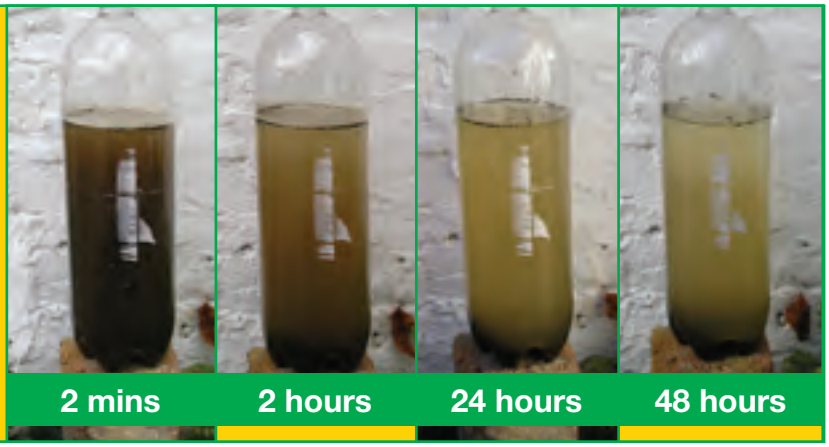
The Environment Agency has estimated that high phosphate levels in around half of England's total river length and a quarter of its lakes mean that they may not achieve Water Framework Directive objectives by 2015 (see Legislation, page 18).

High levels of nitrogen and phosphorus can cause pollution in rivers or lakes and impact on biodiversity and water quality. These nutrients are lost from agricultural land through a combination of land management practices, land vulnerability and climatic factors.

They are key contributors to the pollution of surface and ground waters. Water flowing over the soil surface can carry particulate and water soluble phosphate with it, for example. According to *Defra's Water Strategy 2008,* 25% of phosphorus in UK water bodies comes from agriculture.

The scourge of brown water

Brown water carried into water courses takes nutrients with it. This photo sequence shows how long it takes for brown water running off a field to settle out in a bottle. It indicates just how much suspended solids remain in water run-off even after a full 48 hours period.



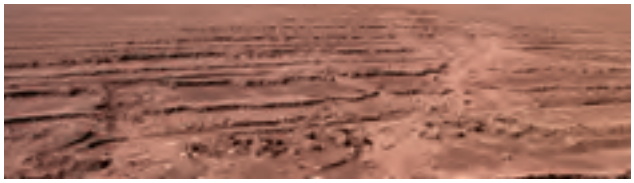
Eutrophication

When a surface body of water is enriched with nutrients, this accelerates algal or plant growth that leads to undesirable changes in water quality and disturbance of the ecology within the water body.

Steps growers can take to avoid eutrophication

- Try to prevent soil erosion taking place and avoid applying animal manures, especially slurries, to waterlogged or very dry soil when rain is imminent
- Maintain soil phosphate levels at the optimum point for potato crop production and soil type (refer to RB209)
- Keep records of phosphorus balance for each field and check a near neutral balance is maintained by soil sampling and analysis every 4-5 years
- Adjust fertiliser application to allow for the phosphorus in organic manures
- Be aware of compaction if overworking the soil
- Leave the soil surface protected with stubble or a cover crop for as long as possible before cultivating the land
- On fields where erosion risk has been identified consider growing an earlier variety, which may allow you to establish an autumn crop after harvest
- Following harvest, where conditions are dry enough, carry out a tined cultivation to break up the surface if you are not establishing an autumn-sown crop
  - This has the added advantage that the operation will leave groundkeepers close to the surface and therefore more likely to frost
  - Carry out the operation as early as possible after harvest to allow water to infiltrate the soil and reduce the risk of erosion from bare and rutted surfaces

2 Soil-related problems



Slopes and water run-off

Steep sloping fields are often prone to erosion of drills, resulting in soil, fertiliser and pesticide loss and green or diseased potatoes. Water will run off the slope if the rate it falls is greater than the rate it can enter the soil – the **infiltration rate**. Maintaining a high soil infiltration rate will reduce surface run-off. This can vary within a field as well as between fields.

Reduction in infiltration rate with slope

Slope Degrees	Reduction in infiltration rate %
2-3	10
3-4	20
5-7	40
7-11	60
Above 11	75

Reference adapted from Bill Basford Potato Council Workshop 2002

Factors that influence infiltration rate

- Soil texture, structure (compaction), porosity and bulk density
- Groundcover
- Slope and dispersion (separation by water of soil particles)
- Depth – subsoil infiltration rate is often lower
- Capping after heavy rain, making free-draining soils susceptible to run-off
- Fields with long, uninterrupted slopes

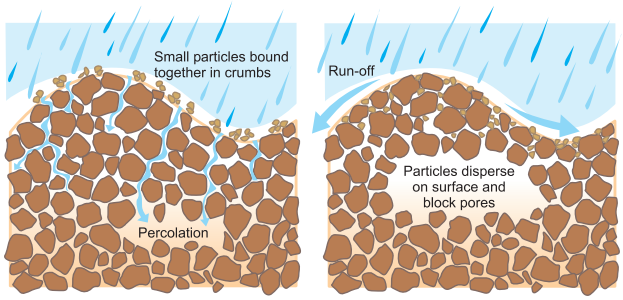
What growers can do to reduce run-off

- Retain more surface cover
- Increase the organic matter content in the topsoil
- Improve soil structure through increasing soluble carbohydrates in the soil, the 'active SOM'
- Relieve compaction
- Break up surface capping
- Break up impermeable layers by subsoil cultivation, if appropriate

- Use **tied ridges** in furrow bottoms
- Use a Simba Aqueel™ on ridge or bed tops (see photo)
- Divide long slopes with grass buffer strips or unplanted cultivated areas

Capping

Soil aggregates are susceptible to breakdown into smaller aggregates when relatively dry soil is suddenly wetted by water. This is known as **slaking.** Soil particles can also separate from one another in water, known as **dispersion**. The two processes, separately, or together, can lead to surface **capping** and interrupt the movement of water and air into the potato ridge.



Capping can prevent the emergence of developing stems, or the collar of hard soil can restrict or damage emerging stems. If not recognised, a large number of seed tubers can die. Adding fresh organic matter can reduce the risk of slaking.

Irrigation

Rain guns can discharge large droplets of water, which can damage the soil or crop foliage. The biggest single fault observed with rain guns is running them at too low a pressure. Maintaining the correct rain gun pressure ensures correct atomisation (typically 4-5 Bar pressure at the gun for 72m lane spacing). Using the appropriate nozzle ring minimises the impact energy of the water droplets. Too low a pressure also results in poor distribution and shorter throw of water across the working width.

Boom irrigators produce finer droplets and so reduce erosion risk. The wetted front of the watering pattern from a boom is narrower than from a rain gun, so the soil infiltration rate needs to be higher.

Growing crops in flat-topped or centre-dished beds together with the use of the Simba Aqueel™ (see photo above) allows the water to remain near the surface without run-off for longer. This means less erosion risk and more water infiltrating into the soil.

Irrigation application rates should be reduced if:

- Soil shows visual signs of erosion or where soil is bare
- Slope is more than 3 degrees (a commonly used maximum infiltration rate on steeper slopes is 10mm per hour)

See also Managing the risk of Common Scab PCL 2010 and Common Scab Cost Benefit Analysis 2011

Compaction

Soil compaction is the increase in bulk density usually caused by pressure on the soil. Pore space reduces as the air or water is squeezed out. The load applied, through a tractor wheel, for example, is greater than the soil structure can stand. The soil deforms and the tractor sinks.

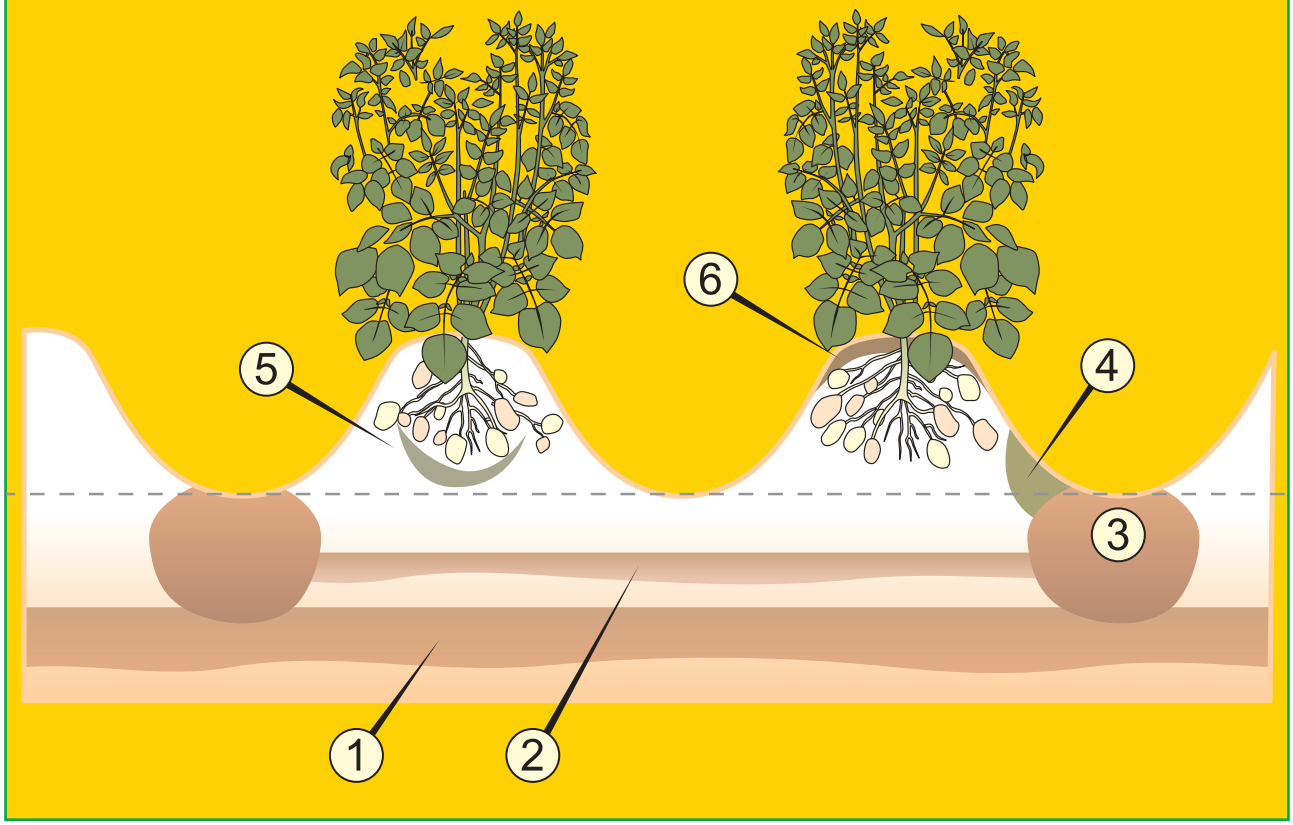
Near the surface, compacted layers of dense soil formed underneath the ridge are often attributed to using heavy machinery and cultivating the soil when wet.

At depth, compacted layers may be a result of heavy harvesting machinery or trailers from previous crops, at times when the soil was too wet to support the high axle loads. The need to plant crops within a limited time window increases the risk of working the soil in an inappropriate condition.

Some degree of soil consolidation is needed for crop growth – good contact with the soil helps root anchorage and allows water uptake. If there is not enough consolidation of the soil around the tuber at planting time crop emergence is delayed. The ridge will slump with a potential increase in some tuber skin diseases such as powdery scab and black dot. It is only when the degree of soil compaction prevents optimum crop growth that it becomes a problem.

Areas where soil problems can be found in potato crops

1. Compaction pan below plough depth, resulting from ploughing the soil when wet or from previous cropping operations
2. Compaction pan caused by bed tiller or separator just above plough depth
3. Compaction in wheelings is normal, but should not extend under the bed. The further it does, the greater water run-off and the less water that is available for the crop
4. Compaction at the base of the ridge will prevent water that has been shed by the drill profile entering the soil
5. Opening coulters on the planter can cause localised compaction below the tuber
6. Ridge-capping can occur from very fine soil particles that 'cement' together sealing the ridge. The lack of air leads to high death rates of seed



2 Soil-related problems

Potato rooting and sensitivity to compaction

The shallow rooting of potatoes is often due to the fact that they are more sensitive to unfavourable soil conditions than other crops. Potatoes extract less water from each soil layer and have about half the effective rooting depth of cereals. This makes the crop's leaf growth rate and canopy development unusually sensitive to low soil moisture.

Symptoms of compaction in potatoes

- Uneven and/or delayed emergence
- Stunted plants with delayed canopy cover
- Reduced rate and density of rooting
  - Reduced availability of soil water
  - Increased irrigation requirement
  - Increased fertiliser requirement
- Premature senescence
- Wilting leaves on hot days even though the soil is moist
- Slight or severe yield reduction
- Increasing tuber deformities, such as cracking, secondary growth, powdery scab, lenticel eruption
- Waterlogged soils
- Water erosion
- Harvesting problems
  - Share penetration in hard soil
  - Clods
  - Waterlogging

Early growth stages

Potato roots are most sensitive to compaction during the first 3-4 weeks after emergence when growth rates of roots are most rapid. Shallow compaction immediately below the seed is more damaging than deep compaction since it is encountered when roots are growing most rapidly.

Nutrient uptake

About 85% of total nitrogen uptake occurs by 45-65 days after emergence; so restricting early root growth can have serious consequences. Compaction reduces nutrient uptake in a number of ways:

- It restricts the extent of the root system, reducing a plant's capacity to uptake nutrients
- It reduces the movement of nutrients through the soil, which lowers nutrient availability
- Compacted soil in wet conditions can result in:
  - A 30% reduction in mineralisation of nitrogen in organic matter to nitrate
  - A 20% increase in loss of nitrogen by denitrification of fertiliser nitrogen

Variety

The determinacy of the variety (a measure of the crop's capacity to maintain leaf production after the first appearance of flowers) will affect rooting depths. Indeterminate varieties such as Cara or Maris Piper will have deeper roots than determinate varieties such as Estima or Lady Rosetta.

Sandy soils

These are generally regarded as not prone to compaction. But sandy soils can and do compact, often quite severely. Unlike other soils they will not recover with time as they do not shrink and crack when drying out.

Their low available water capacity means the presence of a pan in a sandy soil can have larger effects on crop growth than in other soil types. So it is important to examine sandy soils and treat them appropriately to ensure optimum rooting depth.

Factors that can contribute to soil compaction

- Water content of soil during cultivations (damage often occurs when surface is dry but soil is wet below)
- Ground pressure/draft force exerted on soil
- Tyre characteristics and weight supported
- Number of passes of wheels/machinery
- Soil cultivation equipment

2 Soil-related problems

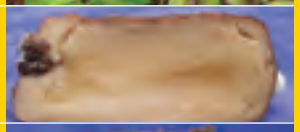
Travelling on soils

To keep compaction to a minimum, soils must be drier than the plastic limit when you travel on or cultivate them. Heavy machinery with a small soil contact area (on narrow wheels, for example) will apply a high ground pressure. Driven wheels or tracks from machinery that produces high draft forces (pulling) cause additional problems. The soil can shear in a plane at an angle to the surface, rather than vertically downward as a normal load.

Reducing the risk

- Reduce the weight of the machine
- Try to spread the load over a wider area. Care is needed as reducing the weight on a driven wheel can lead to increased wheel slip. This can increase compaction and smearing, rather than reduce it
- Spread the load over a larger area by selecting radial tyres that have a larger footprint than cross-ply tyres
- Reduce the tyre pressure to that recommended by the manufacturer for fieldwork. Often tractors can be found working in fields with tyres at high pressures used for roadwork. High pressure reduces the contact area of the tyre and increases compaction and wheel slip

Potato diseases particularly affected by waterlogging

Blackleg *(Pectobacterium carotovorum* subsp. *atrosepticum)*	Occasionally serious, particularly in wet seasons, irrigated crops and on poorly drained land. During crop growth infected seed tubers rot, release bacteria, and infect progeny tubers. In poorly drained, waterlogged soils the seed tuber rots earlier and the risk of tuber infection is greater.	
Rubbery rot *(Geotrichum candidum)*	Outbreaks are invariably associated with heavy irrigation or following rain within three weeks of lifting, especially in warm weather in panned, poorly drained soils.	
Pink rot *(Phytophthora erythroseptica)*	Usually confined to patches in crops where the drainage is poor. Control relies on maintaining good drainage and a wide rotation.	
Watery wound rot *(Pythium ultimum)*	It is important to improve drainage and not to grow potatoes in fields with a history of the disease.	
Powdery scab *(Spongospora subterranea)*	Risk depends on factors such as soil type (moisture retention), drainage (avoid poorly drained fields), and previous history of powdery scab.	

Source: Potato Council Research review, Soil compaction and potato crops 2005, www.potato.org.uk/publications/r260-review-soil-compaction-and-potato-crops

Field operations and position of possible compaction

	Position	
	Wheelings	Under the bed
Plough	✘	✘
Deep Tine	✘	✘
Bed Former	✘	-
Bed Tiller	✘	✘
Fert. Broadcast	✘	-
Separator	✘	✘
Planter	✘	✘
Sprayer	✘	-
Irrigation	✘	-
Flail	✘	-
Harvester	✘	✘
Trailers	✘	✘

Field selection

For healthy roots and good crop growth, potatoes need soil that is:

- well aggregated
- stable
- aerated
- free-draining
- biologically active

Target market and variety should be considered. The table below shows field situations that should be avoided.

Variety trait/market requirement	Avoid
Sensitive to cold soils	Heavy soils that are wet
Bright skin finish	Abrasive sandy soils
Drought-sensitive	Sandy soils
Salad crops	Soils with high stone content
Early market	Heavy, cold soils

Field history

Potatoes are grown in rotation, so the use and management of the field in years prior to potato production is important. Previous crops may have a bearing on soil structure, contribute to compaction problems or cause tuber damage at harvest. For example:

- Trash and divots from fields previously in grass will present problems for separators
- The late harvest of sugar beet could leave serious compaction problems

Field layout

There are a number of factors to consider when deciding the best way to plant a field:

- **Water run-off** from slopes and irrigation lines
- **Soil type** should be consistent along the row for easier harvesting and agronomy
- **Drill wheelings** need to match other machinery – starting harvest can be a problem if trailer track widths don't line up
- Aim for **straight drill lines** to ease machinery set-up
- The **headland** warrants special attention
- Consider leaving it unplanted as this is where most **bruising** occurs
  - If sown with a **grass margin** mixture, it will provide a water intercept and result in lower soil compaction problems
  - If planted, allow ample room for turning and spray tramlines – the ends of drills can become flattened by tyres, causing tuber damage

Buffer strip ©ADAS

Checklist for the autumn before planting potatoes

Inspect the field and examine the soil to a depth of at least 500mm and preferably 700mm in several areas of the field. Look for and identify any problems with:

- Soil structure
- Compaction pans
- Potential water run-off
- Soil texture
- Drainage problems

Subsoiling

Serious compaction problems are usually caused by previous cropping activities that had not been rectified before planting potatoes.

- Check to identify if it occurs all over the field or only in local areas that can be individually treated
- Decide if or when soil conditions are suitable to rectify the problem
- Try to subsoil at right angles to the direction of proposed drill lines

The late summer or autumn, if dry, is generally the best time to carry out subsoiling.

- The previous crop will have removed water at depth, drying the subsoil
- This allows satisfactory shattering of the subsoil
- Avoid subsoiling when the soil is wet and in a plastic state as this could make conditions worse
- Sandy soils, which are never plastic, can be subsoiled during most of the year and should be subsoiled as close to planting as possible to reduce the effects of re-compaction

Cultivations

Managing residue and trash

Difficulties can occur where there is heavy trash residue especially with stone/clod separation. Excessive trash will pass over the separator and fill the furrow bottom.

Farmyard manure (FYM) can also cause problems for separators if not well broken down by planting time. Ensure that FYM is spread evenly and there are no large lumps. More information on nutrient analysis can be found at www.ahdb.org.uk/projects/documents/AHDBImprovedanalysisofsolidmanuresandslurries.pdf

Ploughing and soil moisture

- A field that has been ploughed and left for several months will have formed natural drainage channels and wormholes, allowing easier water movement
- This means it is quicker to dry out in the spring
- It is often drier than a soil that has been ploughed for only a few weeks
- A field ploughed immediately before planting will be drier (if not rained on after ploughing) than one ploughed a few weeks previously and rained on

Managing constraints of the weather

Working the soil speeds up drying. But worked soil that is rained on will hold more water than unworked soil. Soils with high silt and clay contents need very careful timing of operations. Either too dry or too wet can make it impossible to achieve a satisfactory tilth. This increases clod formation and compaction.

Ploughing problems

Severe soil structure problems can be created if ploughing is carried out when the soil is wet.

- If the soil surface is already compacted from previous cropping and inverted when wet there is a tendency for it to go over as a continuous lump that can form an anaerobic layer at the plough share depth
- If the tractor wheel is run in the base of the furrow severe compaction can be created by wheel slip, which is greater in wet conditions or with high draft forces
- You can reduce compaction if the tractor wheels are kept on the surface when using high-powered tractors (on top as opposed to in-furrow)
- The plough share can also cause localised smearing of the soil when wet

Pre-ridging cultivation

The benefits of deep tine cultivation

- Pre-ridging work helps to loosen stiff soil at around 250-350mm and allow the deep ridger to work correctly – stiff soil at this depth will prevent the deep ridger penetrating the ground properly
- Stiff soil can easily pull the tractor off-line, making it hard to maintain a straight line
- Pre-ridging work also helps the soil to dry out by bringing wet soil to surface
- Avoid adding subsoiler tines to bed-formers unless working in sandy soils as the soil at depth will most likely be plastic and exacerbate any existing compaction

Tips for success

- Check soil conditions by digging down to 300-350 mm; if it is easy (don't have to stand on spade), no pre-ridging work is required
- Watch for operators going too fast and the tines riding up out of the ground
- Check working depth

Problems

- Wheelings if wet
- Smearing under the tine

Deep ridging / bed opener

Deep ridging will bring a considerable quantity of wet 'raw' material to the surface.

- Leave this material to dry out for 1-2 hours before bed-tilling or separating but not for prolonged periods as clods become more stable and may require excessive extra cultivation to break down

Problems

- Smearing at the base of the furrow – often the start of a serious problem for water movement, resulting in run-off
- Smearing on the side of the ridge will dry and form hard clods

3 Addressing the issues

Deep bed-tiller

- For optimum output match separator and bed tiller work rates and only bed-form as deep as required for the de-stoning operation
- A good operator can alter the forward speed depending on soil conditions: faster when soil is easy to work and slower in cloddy/sticky areas

Problems

- Pan, created by action of blades at base of cultivation depth. Some types of machines can produce very serious pans. Extent of problem depends on:
  - blade type
  - rotor speed and forward speed
- Excessive tilth at this stage produces fine soil particles that can lead to increased capping and ridge slumping
- An increased risk of soil erosion by wind and by water on sloping sites

Separator

Do you need one?

- While needed for stones, clods will break down to a certain extent during the growing season
- Widespread use of Dalhman-type cleaning units on harvesters ensure clods now present fewer problems

Operate at the right depth

- Go too deep with the separator and too much wet material comes over the machine that cannot be broken down and is discharged to the wheeling
- **Check the discharge** – there should be no usable soil in the furrow base
- There is little benefit in producing de-stoned beds deeper than 25cm on any soil. This depth of bed allows sufficient soil to plant and harvest tubers without damage
- Soils with moderate (20-30%) clay content will frequently be in a plastic state below 25cm at planting and cultivating deeper will result in compaction which will reduce yield
- Separating soils shallower than the normal 30-38cm depth will speed up the operation allowing more timely cultivation, reduce fuel and labour costs and decrease machinery wear and breakdown time

Problems

- Compaction pan created by share
- Compaction at side of bed from separator tyres if not correctly aligned or when travelling across slopes

Planter

Slopes

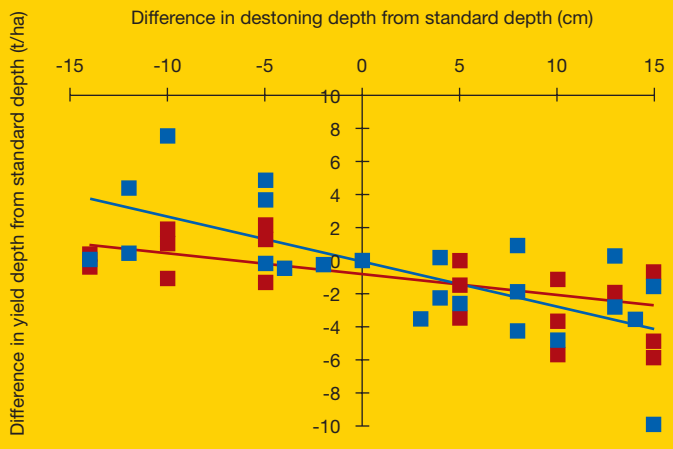
- The high centre of gravity of the hopper can often cause the planter to skew down a slope, making the tractor slip off the stone windrows on to soft soil of the next bed

Destoning shallower than the typical depth used by growers (30-38cm) can result in higher yields on soils with higher clay content and have no detrimental effect on yield on sandy soils.

Figure: Effect of destoning depth on yield 2011-2012

- — Loamy sands and sandy loams
- — Sandy clay loams and clay loams

(Source: CUF 2013)



- Wheel steerage on the planter can help but the wheels may produce a rut or compact the adjacent drill
- If using quad planting and/or covering hoods check to see that there are no compaction issues arising from their use

Problems

- Planter weight with full hopper on the small tyre size causing compaction
- Operation on side slopes can result in compaction on adjacent drills
- Localised compaction from opening coulters around where tubers are placed
- Covering bodies and hoods causing smearing that can later cap and impede crop emergence and cause anaerobic conditions

Subsoiling post-planting

Conditions are rarely favourable for subsoiling to be effective after planting, although some growers are convinced that the crop has benefited from undertaking this operation.

Is it needed?

- First examine the field or area where you think there may be a problem
- Confirm that there is a problem and gauge its extent
- Check if the soil is dry enough at the depth of proposed operations
- Subsoiling after planting should only be considered on fragile sandy soils

Problems

- Subsoiling the centre of the wheelings can lift or push buried stones back into the ridges
- Tractor wheels sink into the aperture during spraying and harvesting operations

Alternative solutions

- Consider using a 'tied ridger' type system to reduce run-off in wheelings
- Check for compaction and alleviate any found at the base of the drill edge, at the side of the wheelings (see photo top right)

Loosening compaction on the shoulder of the ridge using tines mounted on the front of a rotary hiller also allows greater water infiltration and crop rooting.

Spray lines / irrigation lines

Problems

- Compaction and ruts in wheelings lead to water collection and rill formation
- Problem made worse through:
  - Narrow tyre sizes supporting heavy equipment
  - High number of passes in season
  - Timing and number of blight sprays irrespective of soil moisture

Solutions

- Try creating an extra wide area for the wheels at the spray line only, which allows wider tyres to be used on the sprayer
- Use a wider wheelbase width
  - Pull the ridges in closer together under the spray tramlines
  - Try both measures
  - Use a wide sprayer (36m) which fits in with the irrigation lines (72m) to reduce the number of spray lines and associated crop losses at the spray line

Harvesting

Problems

- Weight of harvester – historically the greatest threat of compaction to soils
- Weight of trailers – now the size is such they often have highest ground pressure
- Double or triple axles of some trailers can make turning on soft ground require a lot of power that can result in excessive tractor wheel slip
- High number of passes on headlands

Compliance

Resolving any compaction problems soon after harvest is not only good for your soils – there are legislative requirements when harvesting wet fields

Code of Good Agricultural Practice for Farmers, Growers and Land Managers: Protecting our Water, Soil and Air

It is the responsibility of every grower to have available the most up-to-date version of the Code of practice together with cross compliance requirements.

Content

The code of practice covers all aspects of agricultural production, particularly as it interacts with the environment, including soil management. The guide discusses in detail most soil issues, including key actions that can be taken to protect and enhance the quality of the soil apart from the nutritional and pesticide aspects.

Guidance on nutrition can be found in Potato Council's *Crop Nutrition for Potatoes* and DEFRA RB209 – *Fertilisers for Arable and Horticultural Crops*. More on pesticide usage can be found in the *Code of Practice for Using Plant Protection Products* – DEFRA and Welsh assembly. The Scottish Executive has published a Code relevant to Scotland.

Wales

Growers in Wales are encouraged to grow grass leys one year in five or incorporate bulky organic manures. This is probably not possible in the more intensive arable areas of the UK because of lack of availability of organic manures.

Scotland

The Farm Soils Plan provides a similar function to England's Soil Protection Review, but is not a requirement under GAEC (Good Agricultural and Environmental Conditions).

The Prevention of Environmental Pollution from Agricultural Activity (PEPFAA) code only briefly addresses these issues, and needs to be supplemented by land management information.

Soil strategy

The Environment Agency in England and Wales already has one and the EU is developing its own. The latter is expected to cover many of the points made in this guide as well as the restoration of soils following industrial activity and the need to prevent 'soil sealing' – i.e. being built on.

Cross Compliance

Soil Protection Review

The purpose of the Soil Protection Review (SPR) is to tackle degradation threats to soil. Anyone who receives support under Single Payment Scheme (SPS) must meet the GAEC standards for soil management and protection, as well as all the other relevant standards that are set out in *The Guide to Cross Compliance in England.* This includes new entrants to the SPS and/or Schemes such as Entry Level Stewardship (ELS).

The revised SPR incorporates all four soil GAECs which were previously applicable to soil:

- Soil Protection Review (GAEC 1)
- Post-harvest management of land (GAEC 2)
- Waterlogged Soil (GAEC 3)
- Crop residue burning restrictions (GAEC 4)

Water Framework Directive (WFD)

This is one of the most important soil and water related pieces of legislation that will have a particular impact on land use and management. The main approaches adopted by the government to implement farming elements of the WFD requirements is to use:

- The Catchment Sensitive Farming Delivery Initiative
- Single Farm Payment
- Environmental Stewardship schemes

The WFD came into force in the UK on December 22, 2000. It sets out a timetable for member states to transpose the directive into laws. It also stipulates when requirements should be implemented. The key issues relating to the WFD are:

- That it applies to **all** waters
- It aims to tackle **diffuse source pollution** (e.g. from agricultural and urban run-off)
- It introduces **ecological water quality** for the first time and this includes hydro morphological aspects – the changes in depth, structure and flow of water bodies
- It demands **cost effective** measures and full **cost recovery**

The impact of the WFD on current activities is dependent, for each water body (river, lake, aquifer, etc.), on its current water quality status and on what 'good status' will mean. The first requirement is to ensure no deterioration and the second is to achieve 'good status'.

Good Agricultural and Environmental Condition (GAEC) main requirements

- Do not work or travel on waterlogged land unless there is a need to improve drainage
- Leave the land in stubble or rough cultivated over winter to allow excess rainfall to infiltrate into the soil
- Do not create the final seedbed for spring-grown crops until it is really needed, the objective being to reduce the potential for soil erosion by water over winter
- (England) Produce a Soil Protection Review and review it annually
  - List problems, such as erosion and compaction
  - Action to alleviate them

4 Legislation

Soil Framework Directive (SFD)

The EC adopted the Thematic Strategy for Soil Protection on 22 September 2006. This contains a Communication, a Soil Framework Directive (SFD) and an Impact Assessment. The proposed SFD was blocked in a vote by European ministers in late 2007, but it is likely to be re-introduced, either in whole or in part.

The SFD duty of care requires:

- The restoration and remediation of degraded soil to a level of functionality consistent at least with current or approved future use
- Member states shall ensure that any land user whose action affects soil in a way that can reasonably be expected to hamper significantly the soil functions is **obligated** to take precautions to prevent or minimise such adverse affects

Other Directives

Those that are having or will have an impact on land use and farming include:

- Habitats Directive
- Pollution and Prevention Control Directive
- Environmental Liability Directive
- Sludge Directive
- Waste Framework Directive

Sources of information

Legislation, guides and codes of practice

Defra publications

- *Code of Good Agricultural Practice for Farmers, Growers and Land Managers* (Defra 2009)
- *Cross Compliance Guidance for Soil Management* 2010 Edition (Defra)
- *Cross Compliance Soil Protection Review* (Defra 2010)
- *Irrigation Best Practice, Water Management for Potatoes a Guide for Growers*
- *Code of Practice for Using Plant Protection Products* (Defra 2006)
- *RB209 – Fertilisers for Arable and Horticultural Crops* 8th Edition (Defra 2010)

Scottish Executive publications

- *The Prevention of Environmental Pollution from Agricultural Activity Code, 2005*
- *Farm Soils Plan Protecting Soils and Income in Scotland*
- *Code of Practice for Using Plant Protection Products in Scotland*

Department of Agriculture and Rural Development (Northern Ireland)

- *Code of Good Agricultural Practice for the Prevention of Pollution of Water, Air and Soil*, 2003

Potato Council publications

- Applied Research Forum Soils Information Gateway
- Research review: *Effects of Soil Compaction on Potato Growth and its Removal by Cultivation,* 2005
- *Compost use in agriculture,* 2004
- *Soil, water and other legislation: impacts on Scottish potato production,* 2008
- *Soil water and other legislation: impacts on UK potato production,* 2007
- *PCL Research Review – Soil compaction and potato crops,* 2005
- *Review of non-water control measures for potato common scab,* 2005

Technical notes and other publications

Stalham, M. A., Allen, E. J., Rosenfield, A. B. & Herry, F. X. (2007). *Effects of soil compaction in potato (Solanum tuberosum) crops. Journal of Agricultural Science. Cambridge 145, 295-312.*

Critical Levels of Soil Organic Matter MAFF Project Code SP0306

Hatley, D. L. J. Garwood, T. W. D. & Johnson P. A. 2002 *The Impact of Changing Farming Practices on Soil Organic Matter and Soil Structural Stability of Fen Silt Soils* Proceedings BSSS conference Edinburgh 2002

Sustainable Management of Soil Organic Matter, edited by RM Rees, B.C.Ball, C.D. Campbell and C.A.Watson, CABI Publishing 2001

Greenland et al, (1975) *Determination of the Structural Stability Class of English and Welsh Soils.* Journal of Soil Science 26, 294-303

Updating the Estimate of Sources of Phosphorus in UK Waters, Defra-funded project WT0701CSF

Phosphorus in Agriculture in Relation to Water Quality, AE Johnston and CJ Dawson, Agricultural Industries Confederation, Nov 2005

Plant Roots – Growth, Activity and Interaction with Soils, Peter Gregory, Blackwell Publishing 2006

MAFF Technical Bulletin 29, *Soil Physical Conditions and Crop Production,* 1975

A Guide to Better Soil Structure, National Soil Resources Institute, Cranfield University, 2002

Visual Soil Assessment, Soil Management Initiative and Väderstad

Soil Husbandry – A Guide to the Use and Management of Soils, Tom Batey, published by Soil and Land Use Consultants, 1998

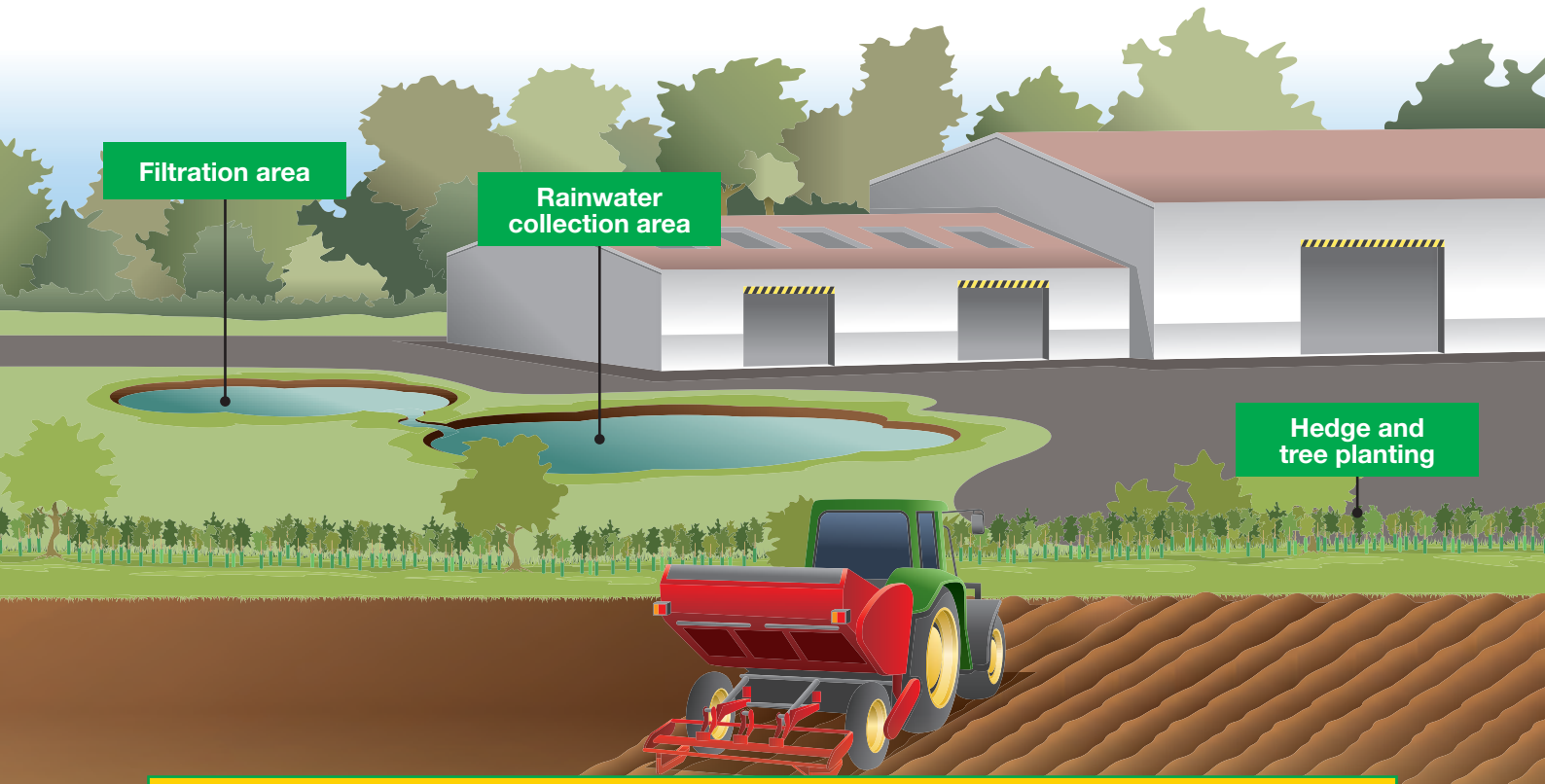
Irrigated Crops and Their Management, Roger Bailey, Farming Press Books, 1990

Russell's Soil Conditions and Plant Growth 11th Edition – Edited by Alan Wild, Longman Publishing Group, 1998

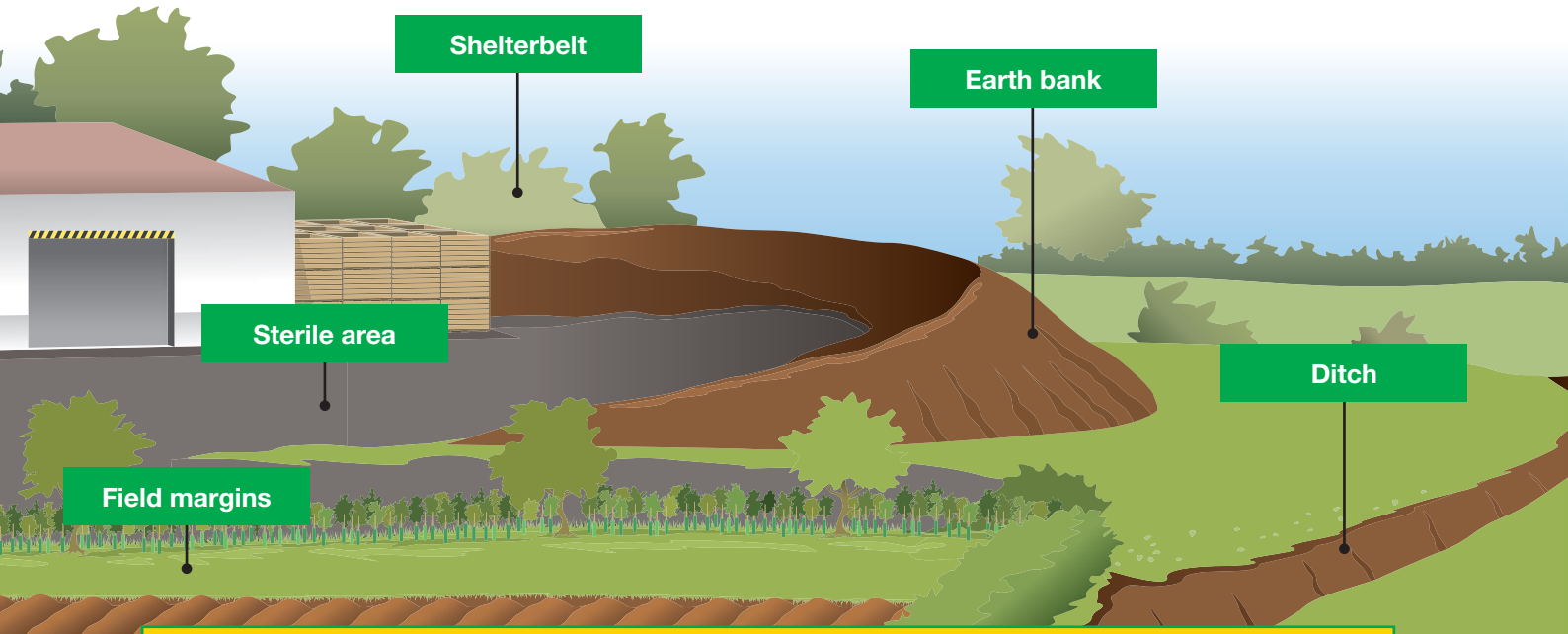
Soil Survey of England and Wales Regional Bulletins, National Soil Resource Institute Cranfield 1984

Soil Survey of Scotland, The Macaulay Institute for Soil Research 1982

5 Addressing the issues



Subject	Delete as appropriate	Your response	Action
Land selection			
Are you planning to grow potatoes on any permanent or semi improved grassland?	Yes/No	Yes	Reassess land base to identify alternative fields or complete an EIA assessment.
If there is no suitable alternative landbase have you undertaken an Environmental Impact assessment (EIA)?	Yes/No	No	For details on how to complete an EIA contact the Natural England Helpline on 0800 028 2140 or email: eia.england@naturalengland.org.uk
Are measures in place to protect local habitats?	Yes/No	No	Reassess land base to identify alternative fields.
Are there any known archaeological features in the field likely to be disturbed by cultivations?	Yes/No	Yes/unsure	Contact local Historic Records Service (normally held by the local County Council or Unitary Authority).
Soil erosion risk			
Is the field at risk of generating soil erosion or run off?	Yes/No	Yes	Undertake an individual Field Risk Assessment and install appropriate management measures to minimise the impact from field run off.
Is the field at risk from wind erosion?	Yes/No	Yes	Refer to the Cross Compliance Guidance for Soil Management booklet on appropriate protection measures. Refer to page 7.
Do you have a plan for addressing soil compaction issues?	Yes/No	Yes	Refer to the Environment Agency ThinkSoils manual to assist with the identification of compaction. Refer to the Potato Council's guidance booklet on Soil Management. Refer to page 11.



Subject	Delete as appropriate	Your response	Action
Meeting regulations			
Soil Protection Review (SPR)	**This is mandatory**		Check the Soil Protection Review and ensure the land use measures are implemented. Review the success of these measures and update the SPR accordingly. Record any planned post harvest management measures.
Nitrate Vulnerable Zones	**This is mandatory**		Check the location of land in respect of NVZ designation: www.magic.gov.uk Utilise the latest version of RB209 to calculate crop nitrogen requirements and ensure appropriate records relating to fertiliser and organic manure applications are maintained.
Agriculture waste: are waste potatoes deposited on farm?	Yes/No	Yes	Apply to the Environment Agency for appropriate licenses or exemptions. www.environment-agency.gov.uk/business/topics/waste/default.aspx Ensure any waste potato disposals take place in accordance with EA licence conditions.
Resource Management Planning			
Are all fertilisers applied as part of a recognized farm plan prepared by a FACTS accredited advisor?	Yes/No	No	Prepare a Nutrient Management Plan. Refer to guidance on PLANET www.planet4farmers.co.uk or 'Tried and Tested' www.nutrientmanagement.org
Are all manures applied as part of a recognized farm plan?	Yes/No	No	Prepare a Manure Management Plan.
Does the farm have a Crop Protection Management Plan prepared by a BASIS accredited advisor.	Yes/No	No	Contact the Voluntary Initiative: www.voluntaryinitiative.org.uk
Have you prepared an environmental assessment for the abstraction zone?	Yes/No	No	Contact EA/CSF on how to prepare a plan. www.naturalengland.org.uk/ourwork/farming/csf/default.aspx

Source: Environmental guidance for Potato Production – PCL. CSF and FWAG 2010

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