getting the most from your soil

A practical guide to maximising cultivated land resources

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Cyfoeth Naturiol Cymru
Natural Resources Wales

HYBU CIG CYMRU
MEAT PROMOTION WALES

Hybu Cig Cymru – Meat Promotion Wales
Tŷ Rheidol, Parc Merlin, Aberystwyth SY23 3FF
Tel: 01970 625050 Fax: 01970 615148
Email: info@hccmpw.org.uk
www.hccmpw.org.uk

Natural Resources Wales
Cambria House, 29 Newport Road, Cardiff CF24 0TP
Tel: 03708 506 506
Email: enquiries@naturalresourceswales.gov.uk
Twitter: @NatResWales

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Technical content: Charlie Morgan GrassMaster Ltd, independent grassland specialist.
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'think soils - soil assessment to avoid erosion and runoff' (Davis, M & Smith R, 2008)

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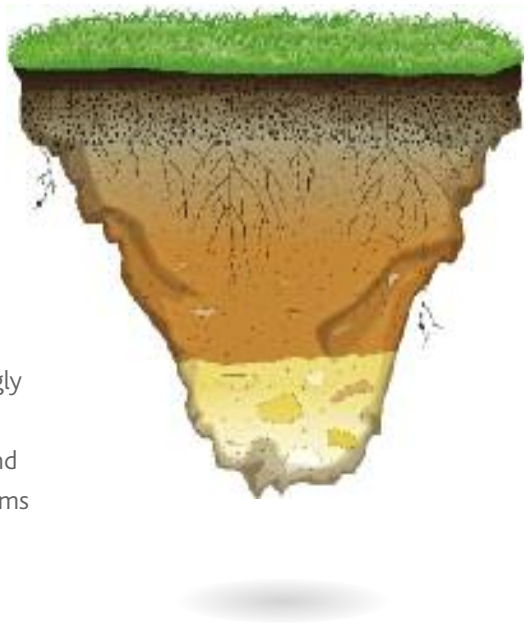


Soil is the most important natural resource on any farm; it influences the choice of grass and forage crops that can be grown on it and the yields and qualities that can be achieved. This in turn has a significant impact on the growth and quality of the livestock that graze or consume them. Soil will impact on the financial, production and environmental outcomes of the farm, yet it is often taken for granted.

A healthy, fertile and well managed soil is therefore a livestock farmer's most valuable asset. So a good understanding of soil and its management is key to developing and sustaining good productivity and to protect the soil as an increasingly important resource for the future.

This booklet provides practical advice that will help producers to better understand their soil and offers simple solutions to address common issues and to avoid problems arising. In this way, sheep and beef farmers in Wales will be able to harness its potential for the benefit of their business and for the environment.

Contents

Soil management... why bother?

The impact of poor soil structure on a livestock farm's bottom line is immense.

Good soil management can extend the grazing period and brings significant savings .

■ The growing season on waterlogged soils is much shorter than that for well drained soils- the soil temperature is too low for early growth and fertiliser applications are delayed when the ground is too wet to take a tractor on.

The cost of concentrate is 3 times more than the cost of grass production so every lost day of grass growth can increase feed costs and reduce margins significantly.

■ Compaction limits root development giving a lower annual yield and an increased risk of drought, pests and disease for an already stressed crop. With the cost of reseeding now estimated to be around £200/acre or £500/ha* and continuing to climb, any loss of yield from poor soil structure is a burden that can't be borne.

*Based on 2011 seed prices

Good soil conditions means that grass can support a higher stocking density.

■ Good soil structure and modern grass varieties can increase the efficiency of nitrogen fertiliser from 60% to 75%. Poor soil structure can reduce this to 40% or less.

This means that 1kgN could produce enough grass to feed 15, 50kg Welsh ewes under good soil conditions but only enough to feed 8 ewes under poor conditions.

■ Temporary waterlogging on compacted soils dictates the winter housing period. It reduces grazing days and significantly costs the farm business. Reducing the housing period and extending the grazing period by just one week either side can equate to an extra £49/head for the weaned calves from a 50 suckler cow herd.

Knowing the composition and condition of the soils on your farm is crucial – read on to find out how you can make the most from your soil and how your soil can help make your farm business more profitable.

First things first - getting to know your soil

The soils on our farms were formed over thousands of years. They reflect the rock from which they were formed, the vegetation that has grown there, the geography of the landscape and climatic changes. Human activity also has a profound effect on the soil that we work with today.

Nothing can be done to change the type or texture of the soil on your farm, but knowing the soil type is the first step to managing it well. Soil type can change from field to field or even within fields. Soil texture is affected by the relative proportions of clay, silt and sand. Sand is the largest particle found in soil; clay is the smallest.

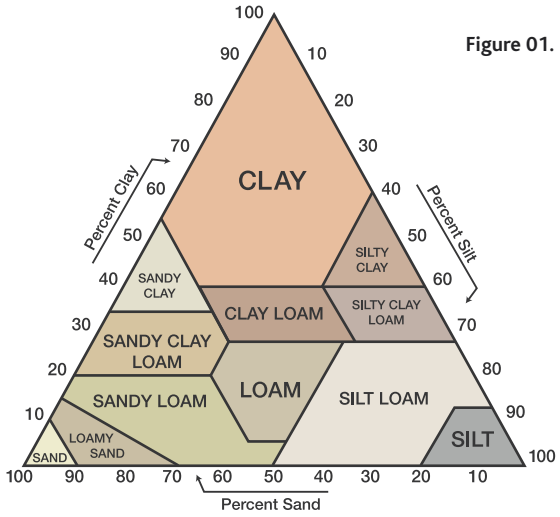


Figure 01.

Sandy soil.

Clay soil.

Sandy soils

- Have large air spaces and water can drain easily
- Have easily worked cultivations and long windows for sowing
- Weeds are easier to control
- But....they lose structure quickly, don't hold water and nutrients well and they erode more easily.

Silty soils

- Have smaller particles than sand and drainage channels are good
- Have relatively easily worked cultivations and reasonably long windows for sowing
- Weeds are easy to control
- But....they can lose structure, don't hold water and nutrients particularly well and can erode easily.

Clay soils

- Have very small spaces so movement of air, water and nutrients can be easily compromised
- Are very stable and hold water well
- Lend themselves well to direct drilling techniques
- Hold onto nutrients such as calcium, potassium (potash) magnesium and ammonium, preventing them from being washed out of the soil
- But.....are more difficult to work and prone to compaction.

Most soils in Wales are a mixture of the different soil types. An even proportion of each soil type is called a loam.

Different proportions of each soil type affect how the soil behaves. Silt and sand create a medium texture loam that has the benefits of both soil types. Clay loams can affect how well different nutrients are held by the soil (***see Figure 01 above***).

Organic (peat) soils

Some soils in Wales are rich in organic matter, dark (peat-like) in its colour and texture, and will stain fingers black or grey. They:

- Are easy to work and very fertile.
- Are usually well structured and soft
- May need consolidation to create good seed/soil contact
- Have more than 20% organic matter content and are extremely valuable in terms of water holding capacity and carbon storage. **For this reason, unimproved soils should not be cultivated.**

Assessing your soil texture - a simple exercise to do out in the field. Knowing the type of soil is the first step to managing it well. Soil type can change from field to field or even within fields.

Clay soils can be worked to a ribbon that can reach around 5cm or more.

1.	Take a fistful of soil and add a few drops of water to wet it (if there is no water available, spit on it!)
2.	Can you work it into the shape of a ball?
	No? Then: If it has a gritty feel between finger and thumb.- it is a **sandy soil**
	If it is dark in colour and contains wood/sedge materials – it is an **organic (peat) soil**
	If it formed a ball, can it be moulded into a ribbon?
	No? Then: It is a **loamy sand**
3.	If it formed a ribbon, how long is the ribbon before it breaks?
	Less than 2.5cm (1 inch) and:
	Smooth and slippery = **silt loam**
	Gritty = **sandy loam**
	Neither smooth or gritty = **loam**
	2.5 – 5cm long and:
	Smooth and slippery = **silty clay loam**
	Gritty = **sandy clay loam**
	Neither smooth nor gritty = **clay loam**
	More than 5cm long and:
	Smooth and slippery = **silty clay**
	Gritty = **sandy clay**
	Neither but can create a smear = **clay**

Soil - a living resource

Soil is not just physical material, it's a living resource that needs air, water and nutrients. Soil is also a major store of carbon – in fact there is three times more carbon in the soil than in the atmosphere and, with correct farming practices, these levels can be maintained or increased, which can help with climate change adaptation and mitigation.

Organic matter plays a vital role in soil structure. It is a food source for biological activity and a major source of nutrients to the plant; it influences water retention, drainage and aeration of the soil. Organic matter also constitutes about 60% of soil carbon.

Most organic matter is found in the topsoil. Soil type affects the organic matter content:

- Wet heavy soils have higher organic matter content than well drained ones
- Organic matter breaks down more slowly in clay soils than sandy soils
- Building up organic matter levels of sandy soils will help to improve crop yields
- Very high organic matter soils (>20% organic matter content) such as peat have a high water holding capacity. This reduces flood risk but gives poorer grass yields as they take longer to warm up in the spring.

A well managed soil should have a minimum amount of organic matter in its topsoil in order to maintain its structure, fertility and carbon bank:

- Light sandy / silty soils > 2.5%
- Medium loam soils > 3.0%
- Heavy clay soils > 3.5%

Soil biology is the foundation for sustainable farming and soil management should aim to maintain or build up soil organic matter, structural stability and biological activity.

On continuous grassland soil organic matter is not usually an issue, these soils usually contain 4-6% organic matter. Arable land has the lowest levels of soil carbon so the rotation of cropping that includes grass breaks is important.

Soil as a carbon store – climate change mitigation

In Wales the vast majority of land is under grass and forage crops and the good levels of organic matter play a key role in carbon storage. Organic matter such as farm yard manure (FYM) provides long-term soil carbon accumulation.

Proportions of carbon converted to soil carbon:

- Straw 5-7%
- Legumes 17%
- FYM 23%

The majority of land in Wales is permanent pasture and nutrient inputs are not significantly high and so grass-fed livestock systems play an important role in minimising carbon emissions, and therefore climate change mitigation. Grass based systems have a major role to play in reducing carbon losses from soil and the efficiency of the system hinges on good soil management.

Organic matter plays a vital role in soil structure.

Soil organisms

There are about 6 tonnes/ha of soil organisms responsible for decomposing organic matter to produce humus and in turn provide nutrients to the plant.

Efficient farms should be able to carry 1.5t livestock / ha (i.e 10-12 ewes plus their progeny or 3 cows). In order to achieve this the earthworm population must be maintained. Healthy soils have a good quantity of earthworms but remember that most soil organisms cannot be seen by the naked eye.

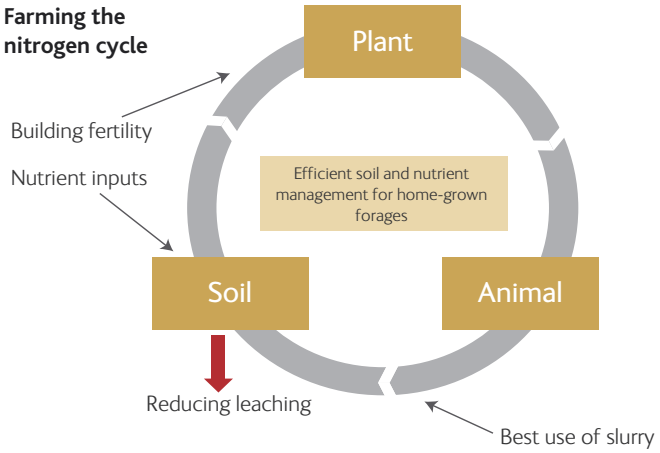
- Earthworms are a visual indicator for how well manures and crop residues are breaking down. They drag organic matter from the soil surface down into the topsoil.
- Insect larvae and mites feed on the decaying organic matter.
- Once the organic matter is incorporated into the topsoil microorganisms such as fungi and bacteria continue the process.

Well structured soil with adequate organic matter and the right proportion of air and moisture will help to maintain soil organisms. These will help to reduce nutrient loss, reduce run off and help to achieve high levels of production.

Soil Nutrients

Livestock farmers effectively farm nitrogen (N). Nitrogen makes up protein and protein is the product sold as meat. Any inefficiency means that the cost of nitrogen used (fertiliser) can actually be more than the return on nitrogen sold (kg meat).

Nitrogen, phosphate and potassium are essential elements for grass growth and needed to achieve good yields. But oversupply both wastes money and damages the environment. All too often the reserves in the soil are overlooked.



	Needed for:	Supplied by:	Consider levels in the soil:
Nitrogen (N)	Plant growth, essential to produce plant proteins.	▸ Soil ▸ Atmosphere ▸ Legumes ▸ Manures ▸ Artificial fertilisers	Soils contain 5 - 15t N/ha. Most soil N is in organic form and unavailable to the plant. In healthy, well managed soils around 1-2% of the total N will become available to the plant in inorganic form during the season. In compacted soils very little N is available for growth.
Phosphate (P)	Root development. Early growth. Winter hardiness. Photosynthesis.	▸ Artificial fertilisers ▸ Manures especially poultry ▸ Human waste	Soil P levels vary from 0.5t/ha to 2.5t/ha. Most P is insoluble - so plant roots have to seek out the soluble P. Excess P (Index 4 and above) will physically leach away.
Potassium (K)	Maintaining plant shape & structure. Moves nutrients and water around the plant.	▸ Artificial fertilisers ▸ High contents in manures ▸ Wood ash	Large reserves of K in the soil - varying from 1t/ha to 75t/ha but only 2% of this is available to plants. Grass takes up K very easily. Fields that have a lot of K are usually grazing fields whilst silage fields that need K are often deficient. A typical silage cut can remove 150kg K /ha (120 units K/acre) which needs to be replaced to maintain yields.
Magnesium (Mg)	Chlorophyll – the green powerhouse of plants.	▸ Mg (dolomite) lime ▸ Kieserite	Deficiency causes staggers. Excess makes soil cultivations difficult and reduces potassium function.
Sulphur # (S)	Protein production.	▸ Artificial fertilisers ▸ Green manures ▸ Atmospheric source now considerably reduced	Very soluble. Hardly any S is stored in the soil. Extremely acidic but essential to maintain high yields especially under cutting systems#. Supplementation can increase yield by 30% on sandy soils and 10% on clay soils.

 # S fertilisers are becoming essential to maintain yields and nitrogen efficiency. Herbage tests are needed to measure S levels.

Testing your soil

Soil tests are the only way to get a good handle on soil nutrient status. It is one of the simplest ways to reduce the cost of production and risk of pollution.

Single tests give a snapshot of the nutrient status in one place at one time. Regular testing gives a history of nutrient management and use across the farm. Nutrient input can then be adjusted for both amount and composition to reduce costs and reduce nutrient losses.

Using soil tests to correct soil nutrient levels will:

- Improve the ryegrass and clover content of the sward by helping them to compete with other species
- Extend early and late season growth patterns
- Increase the total yield over the season
- Reduce competition from weeds
- Improve nutrient efficiency.

Taking soil samples

1. Use an auger or soil corer to take a representative sample.
2. Try to avoid using your hands to handle soil, wear gloves or use a plastic bag.
3. Walk the field in a W shape. Avoid gateways, feeding sites and heavily dunged areas.
4. Twist the corer down to 7.5cm for grassland (and 15cm for arable) and collect around 25-30 plugs of soil.
5. Put them into a bag and mix them well.
6. Take a large mug full of this mixed soil. Place the sample in a plastic bag and seal.
7. Clearly label it and send away for analysis.

When to sample

1. Sample soil **during winter months** to assess fertiliser requirements for the coming season.
2. **Sample at least 3 months after the last application of all nutrients** (manure included) **and at least 12 months after applying lime.**
3. **Repeat samplings at the same time of year so results are comparable.**
4. **Sample regularly**
   - every 3-4 years on intensively managed ground;
   - every 5-6 years on grazing land;
   - every 2-3 years on light sandy soils or in high rainfall areas (800mm rain/year).

Use an auger or soil corer to take a representative sample.

Remember: large fields may have different soil types or aspects so treat each area separately.

What do the results show?
Simple soil tests include measures of pH (acidity) , P (phosphate), K (potassium [potash]) and Mg (Magnesium). These are reported by soil index or by mg/litre.

The ideal chemical analysis for soil under continuous grass			
pH	P	K	Mg
6.0	25mg/L Index 2	180mg/L Index 2-	100mg/L Index 2

Results to date from 1500 fields sampled through the Wales Catchment Initiative showed that:

- 64% of fields had a pH less than 6.0
- 67% of fields do not have optimum levels of P (21% have P indices of 0 -1 with 46% having an index of 3 or above)
- 55% of fields do not have optimum levels of K (39% have a K index of 0-1 with 16% having an index of 3 or above)
- 76% of fields do not have optimum Mg levels (around 2% have a Mg index of 0-1 with 74% having an index 3 or above)

Soil indexes
Soil indexes run from 0-9 with most falling in the range of 0-5. Each index has a wide range of mg/L within it, so mg/L is the more accurate and reliable measure.

The relationship between soil index and mg/Litre.			
Soil Index	Phosphorous	Potassium	Magnesium
	mg/L		
0	0-9	0-60	0-25
1	10-15	61-120	26-50
2	16-25	121-180(2-) 181-240 (2+)	51-100
3	26-45	241-400	101-175
4	46-70	401-600	176-250
5	71-100	601-900	251-350

The cost of soil testing can often be repaid in the first hectare of spring application. "After soil testing right across the farm, I saved £5,000 in fertiliser costs in the first season by using manure from my beef system and buying the right fertiliser to correct the balance." **Rob Wilson, Bwlchyddwyallt, Brecon.**

Soil pH

Soil acidity is one of the most important issues affecting efficient forage production.

The ideal soil pH for grass and clover is **pH 6.0-6.5**. pH levels above or below this cause expensive production losses. They affect nutrient availability which can lead to nutrients reaching the watercourse, affecting water quality and causing environmental damage. Liming is considered expensive and so rarely done. Instead, more nitrogen and other nutrients are applied to achieve the same output. This creates an inefficient system where too much fertiliser is applied and the vast majority is lost.

It costs the farm business greatly but costs the environment even more...

Soil indicator fluid gives a simple and inexpensive colour guide as to how acidic the soil is top: lime, bottom: acid soil.

Making the problem worse...

In Wales the majority of the underlying rock is volcanic and acidic with a few small limestone outcrops. The combination of high rainfall and widespread use of nitrogen, potash and (more recently) sulphur-type fertilisers increases soil acidity. This, coupled with manure applications, continues to acidify the topsoil over a long-term ley or permanent pasture.

Impact of pH on farm outputs

A pH of 5.5 can cause **~10% loss of yield** compared to a soil at pH 6.0. pH levels above 6.5 reduce production in the same way by making key elements less available.

This can equate to a tonne of Dry Matter/ha or 4 tonnes of a 25% DM silage/ha. Being out by one pH unit can cost more than £100/ha each season.

Testing the pH of your soil

Laboratory tests are a cost-effective way to establish the actual acidity of the soil and avoid the over supply of liming products. Soil indicator fluid gives a simple and inexpensive colour guide as to how acidic the soil is.

Indicators of acid soils

Poor grassland production over the season is usually a good indicator that soil is too acidic. Grass that greens up after applying nitrogen but doesn't grow very much is an obvious indicator of soil acidity or compaction.

Remember: deficiencies / other problems can have the same symptoms - a test is the only guarantee.

Managing acid soils
Consider your soil type and the target crop when monitoring soil pH levels.

How much lime do I need?
As a rule of thumb:

- 1 tonne/acre of lime will raise the pH by 0.2 units.
- For example: if the pH is 5.6, an application of 2t/acre or 5t/ha will raise the level to pH 6.0.

Clay soils need more lime to raise the pH by 1 point than sandy soils. Sandy soils leach and lose nutrients faster – so focus on the crop demands and apply the amount needed to give the optimum yield. Sandy soils will need treating little and more often so regular sampling is key.

Applying lime
Two tonnes/acre (5t/ha) is the maximum recommended in a single application on established grassland. If more lime is needed then it should be applied 12-18 months later.

	Target pH	
Cropping options	**Sandy –Clay Soils**	**Organic (Peat) Soils**
Continuous arable	6.5	5.8
Grass/ occasional barley	6.2	5.5
Grass/ occasional wheat/oats	6.0	5.3
Continuous grass or grass/clover	6.0	5.3

Remember: applying too much lime can be costly in terms of both wasted product and poor production.

Back to Basics..... "In 2005 the pH of our soil was 5.2 and 5.3. P was index 4.0 but locked up and inaccessible, like money in an ISA. We invested £12,000 in a lime spreader and by 2010 our pH was up to 6.0 and our P was 3.0 with the grass growing well. The increased grass yield has now more than paid back the investment in the spreader ." **Clive and Gwyn Johnson, Maesbach, Pontypridd.**

Poorly ground products (right) are too coarse and won't break down properly .

Choosing the right liming product
Choose the product based on its neutralizing value (NV), the fineness of grinding and the hardness of the parent rock (visit the Lime Association website at www.britishlime.org).

- **NV is the percentage effectiveness of the product compared to pure Calcium Oxide (CaO).**
  Ground limestone normally has a neutralising value NV of 50-55%. Other products may vary and the application rates must be adjusted to supply the equivalent NV.
- **The fineness of product affects how quickly it works.** Limestone can take many months to have its full effect on soil pH, but if ground to the correct levels will continue to neutralise for many years.
  - Very fine products dissolve faster and work sooner but are lost within 12-18 months.
  - Poorer ground products have bigger pieces of rock which may never breakdown.
- **The source.** Magnesium (Mg) and calcium lime are the common sources. Mg lime will also correct Mg deficiencies but levels can become too high in grassland situations. If the Mg index reaches 5 it will restrict the availability of potassium (K) which will reduce grass yield and nitrogen response. **The choice of Ca or Mg lime is important - cost is not always the driver.**

Without the correct pH losses to the environment are also higher. Lower NV products are very often more soluble and whilst they work well, they will need to be applied more often.

This costs more in fuel and labour and increases the risk of compaction with a higher risk of nutrient runoff.

How the neutralising value (NV) of lime affects the cost		
Compare: ground limestone with an NV of 55% and a cost of £28t delivered and spread With: an alternative product with an NV of 40% and a cost of £22t delivered and spread.		
Cost of Ground Limestone	= (£28 x 100) / 55 (NV)	= **50.9p/unit**
Cost of the alternative	= (£22 x 100) / 40 (NV)	= **55.0p/unit**
So although the price/t of the alternative appears to be cheaper, the superior NV of the lime means that it is more effective than the cheaper alternative!		
Always work on NV and solubility of the product		

Using fertiliser

Before adding fertiliser it is important to know what you need. Soil tests are the best starting point. Common fertiliser products for spring dressings have often been 20:10:10 or 27:5:5 and in the past these have been what the soil needed.

However, soil tests can help to reduce nutrient costs by identifying the nutrients that are actually needed and in what quantity.

Please bear in mind that the nutrient input from manures, slurry and wastes for agricultural benefit (e.g. sewage sludges and dredgings) also need to be considered and that this should be taken into account when buying and applying fertilisers. Either use the Defra RB209 Fertiliser Manual as a guideline or sample the manures so that the right nutrients are applied in the right amounts.

COSTS COUNT:

1 tonne of 34.5% N costs £345	= 345/345x100	= **£1.00/kg**
1 tonne of Triple Super Phosphate (TSP) 46% P costs £450	= 450/460x100	= **98p/kg**
1kg = 2units therefore N costs 50p/unit and P 49p/unit		

For example – Soil test results show that a field has a pH 6.2 P index 2.0 K index 3.0

The crop requirement for spring grazing (RB209 Fertiliser Manual) is 50kgN/ha & 20kgP/ha (P total for the season) with no requirement for extra K (to convert these to units/acre, multiply by 0.8 giving crop requirements of 40units/acre of N and 16units/acre for P).
Applying 250kg/ha of of 20:10:10 will give 50kgN/ha, 25kg P (oversupplied by 5) and 25 kg K oversupplied by 25 units. If applying 2cwt/acre 100kg) 20:10:10 this will achieve the 40 units of N but P will be oversupplied by 4 units and K by 20 units.

This oversupply (at a cost of £0.49/unit P and £0.33p/unit K) has cost £20.65 /ha or £8.54/acre

185kg product /ha will give 50kg N, 5kg P but oversupply K by 15kg. This means that 1.5cwt/acre of 27:5:5, will achieve the 40 units of N but phosphate is undersupplied by 8.5 units and K oversupplied by 7.5 units. Using 26:10:0 at 1.5cwt/acre supplies 39 units/N and 15 units of P and so is the best match for the soil.

A soil test costs £10 so test will have paid for itself in the first 2 acres spread
If the soil result had been pH 6.2, P3, K3 then only nitrogen would have been needed allowing even further savings

Over application of nutrients is money literally leaching away...

Using soil tests to manage soil nutrients

	TOO LOW ▸ ▸ ▸ ▸		IDEAL LEVEL		◂ ◂ ◂ ◂ TOO HIGH
pH	**5** Apply lime Monitor level and effect after 12 months	▸ ▸ ▸	**6-6.5**	◂ ◂ ◂	**7** Alkaline conditions Very difficult to manage Heavy cropping can help – try multiple silage cuts
Nitrogen N	Apply N fertiliser: 50kgN ⟶ extra 2.5t DM 100kgN ⟶ extra 5t DM	▸ ▸ ▸	**Supply crop demand based on yields**	◂ ◂ ◂	Can cause high ammonia levels in silage ⟶ poor intake Excess N lost to the environment ⟶ pollution
Phosphorus P	**1** Apply manure/slurry/ or bagged P Choose right product for the situation Best response is from spring grass	▸ ▸ ▸	**2**	◂ ◂ ◂	**4** Keep to limits in manure management plan Avoid adding anything if at upper limit Substantial environmental risk from over application
Potassium K	**1** Apply manure/slurry/or bagged K Select best value sources like manure – 1t manure has 7.2kg available K Poultry manure has 30 units/t (16kg/t).	▸ ▸ ▸	**2**	◂ ◂ ◂	**4** Oversupply can dilute Mg & cause staggers Avoid application to grazing land in spring Manage manure applications to avoid over supply
Magnesium Mg	**0** Apply Mg lime (15% Mg)	▸ ▸ ▸	**2**	◂ ◂ ◂	**4** Identify fields that are more/less prone to staggers in spring and autumn
Sulphur S	Apply manures and fertilisers To be certain take a forage sample	▸ ▸ ▸	**Supply crop demand based on RB209#**	◂ ◂ ◂	Extremely acidic so avoid oversupply Oversupply can cause trace element problems with Cu and Se leading to infertility in cattle

Download the RB209 fertiliser manual free from the Defra website at http://www.ahdb.org.uk/projects/CropNutrition.aspx

Soil Structure

The size and development of soil aggregates (blocks) through and between which roots, water and air move determine the structure of the soil.

- **Good soil structure –** well formed porous aggregates with rounded edges which can be easily broken between fingers when moist.
- **Poor soil structure –** harder, sharper blocky aggregates which are more difficult to break apart. Makes it hard for roots to penetrate, for earthworms and other soil organisms to break down and for air and water to move through. Poor soil also has difficulty in holding water.
- **Organic matter affects structure.** Soils under grassland usually have good organic matter content, binding the soils and giving a stable structure that is less susceptible to damage.
- **Soil texture** also plays a role in this with sandy and peaty soils having weaker structures that can easily breakdown to individual particles (slump).

Good soil structure promotes good root development.

Farming practices can improve soils by affecting the organic matter content and pH. However farming practices that lead to compaction affect soil structure most critically, these include:

- Long term poaching by livestock
- Repeated heavy machinery traffic
- Plough pans created by repeated cultivations at the same depth
- Cultivations conducted in wet conditions
- Over working of seedbeds
- Smearing of surface soils by wheel slippage or other dragged implements or feeders
- Surface capping by heavy slurry applications, sediments deposited by standing water, light poaching by stock or rain splash on over cultivated bare soil.

Minimum tillage and no tillage

Minimum tillage is a method of sowing crops (including grass) without ploughing. It:

- uses less energy and fuel
- reduces cost of productions
- reduces nutrient loss (including carbon emissions)
- reduces risk of soil particle loss to watercourses.

Occasional ploughing (every 5 years) will create better soil aggregate structure that is beneficial for carbon storage and nutrient capture. Soil aerators and subsoilers will also help the process.

However, it does not address soil compaction damage and problems can still occur with surface runoff, poor rooting potential and reduced nutrient efficiencies.

Compaction – the silent killer

Soil compaction is the biggest single factor that affects production.

Compaction:

- Wastes manure and fertiliser – they simply run-off
- Reduces the soil response to nitrogen applied to as little as 40%
- Lowers soil temperature which reduces grass growth
- Shortens the growing season
- Reduces the yield of grass and clover so that it can't meet production targets
- Creates difficult conditions for harvesting silage and maize

Applying fertiliser and manures to compacted soils is a waste of time and money.

Surface signs of compaction

- Standing water and / or surface runoff.
- Grasses with reddish tinge to leaves indicating stress
- Change in plant species - rushes, marsh thistles and more tussocky or clumpy type grass like Yorkshire fog
- Scorch marks from urine patches where it could not drain into the soil and disperse.

How to identify compaction

1. Dig a square hole to at least a spade's depth when the soil is not too wet or dry.
   - **Was it easy to dig?**
   - **Were there any points of resistance when digging?**
2. Lift out the cube of soil and examine it carefully. Look particularly at:

Topsoil depth – shallower in permanent pasture than cultivated soils

Colour – topsoil rich in organic matter will be dark.

- **Rusty mottles/spots in the topsoil is a sign of poor drainage.**
- **Are there any grey – gleyed areas from temporary or permanent water logging?**
- **Very dark soil near the surface with a distinct line suggests that organic matter isn't being taken down into the soil.**

Smell – if water lies trapped in the soil for any length of time there may be a layer of foul smelling debris.

Roots – should be healthy and reach depths of 30cm plus in free draining healthy soils. They will become stunted and sometimes grow horizontal on compacted ground.

Earthworm activity – there should be 10-15 earthworms in a cube of soil cut with a standard spade.

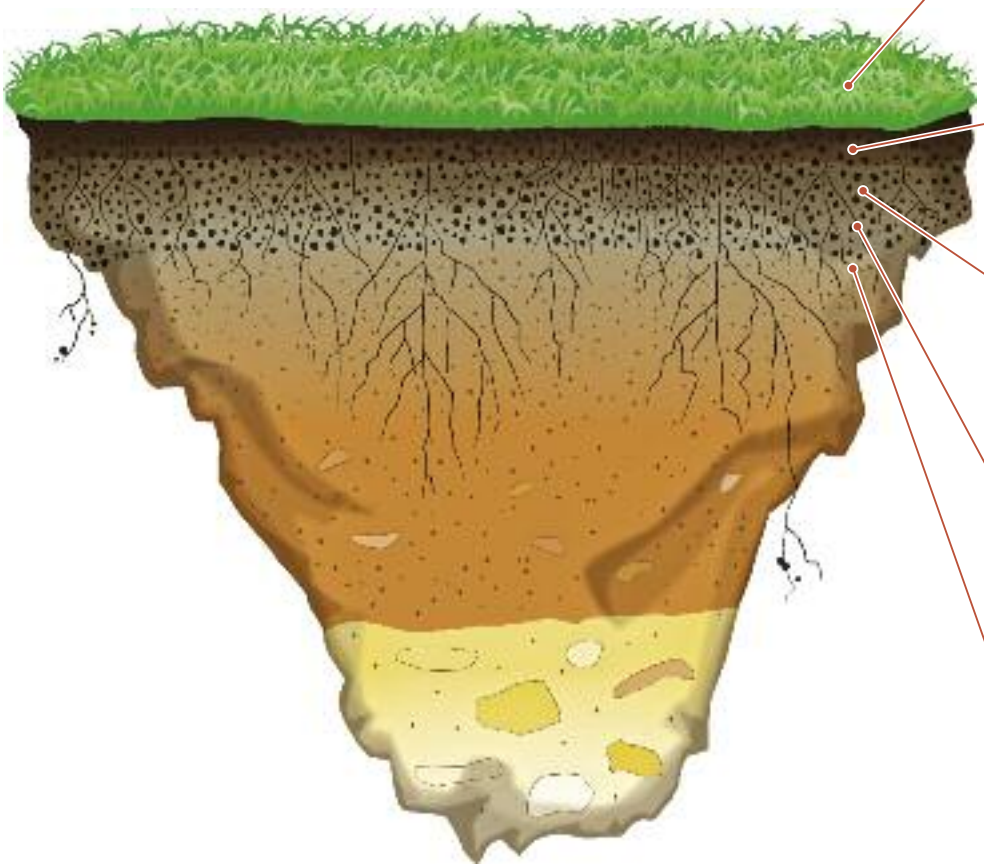
Cracks and pores – the soil should have vertical channels between the soil blocks. Horizontal cracks defines a compaction zone.

Mottles (orange spots) is a sign of soil that is periodically waterlogged.

Identifying likely causes of compaction

The depth of the compaction zone gives an indication of possible causes.

A soil profile



Surface level
Capping on new reseeds.

0-5cm deep
Sheep trampling at high stocking densities eg at lambing time or over winter.

5-10cm deep
Cattle pressure eg. grazing in very wet conditions.

10-15cm deep
Heavy machinery trafficking eg. silage, muckspreading.
Remember: 70% of the damage occurs on the first wheelings.

15cm plus
Plough pan repeated cultivation depth.

Managing soils to reduce the risk of compaction

- Create a stable soil by correcting the lime status and having enough organic matter.
- Correct drainage issues - wet soils are far more prone to damage than dry ones.

Temporary waterlogging on compacted soils costs farm businesses significantly. It is the main factor that dictates the winter housing period and reduces grazing days.

Often spring weather is ideal to turn cattle out and there may be a bite of grass on the fields, but the fields are too wet. Improving the soil structure so that cattle can be housed for a shorter period of time can have a big impact. This may only be a couple of weeks later housing in the autumn and a couple of weeks earlier turnout in the spring but the financial impact is significant.

Take a 50 suckler cow herd plus 10 month old weaned calves.
Consider cost of housing @ £1.50 - £2.00 per head per day.
Cost of housing per 100 hd @£1.75/day = £175/day = £1,225 week.

Extending the grazing season by 1 week either side of housing saves £2,450 which is equivalent to receiving an extra £49/hd for the 50 weaned calves... That's significant!

Practical remedies for compaction

Some soil damage will occur on every farm as the weather (rainfall) has a great influence on the impact of livestock and the movement of livestock is not always possible or, sometimes, permissible.

Machinery can help break up compaction zones and improve soil structure.

The type of machine needed depends on the soil type, texture and the depth of compaction.

To maximise the benefit and avoid any further damage, only use machinery when the soil is dry at the depth that is being managed.

- An arable subsoiler can be used to shatter deep compaction below plough depth. This is best done after ploughing
- A plough set at the correct depth just below any pan can break up the solid aggregates but ploughing is not a viable option for compaction problems in long term leys
- Use a mole plough on heavy clay rich soils in late summer. It creates a drainage channel to feed to existing drains and breaks up any deep compaction layer
- Long term leys or permanent pastures bear the brunt of winter stocking and feeding sites. Oversowing or direct drilling has limited success as it doesn't address the compaction below it.

Always consider the topography of the land when using subsoilers that create drainage channels.

Look at the direction and angle of any slope to control the flow of water from the field.

- Too steep an angle means that water moves too fast risking soil erosion, loss of nutrients and water pollution
- Shallow angles remove excess water without losing soil particles and nutrients
- Plough across the bottom of the slope to reduce risk of soil loss.

Remember – incorrect use of the plough, sward-lifter or aerator in unsuitable soil conditions will only make the situation worse not better and more damage can occur!

Consider an aerator for shallow compaction zones.

Use a grassland subsoiler which is capable of going down to 28-30cm (10-12in) but adjust depth so that it only works at 2cm below the compaction zone.

The right tool for the job...

"I used a grass subsoiler on my heavy clay over a period of 2-3 years and got more grass since the soils were better drained and warmed sooner in the season. It extended the season by 2-3 weeks but the mole plough has had the greatest impact as it doesn't need to be repeated as often as the subsoiler. In areas where the mole plough is not suitable the subsoiler is the next best option."

Keith Williams, Hendy, Hundred House

A subsoiler creates drainage channels so make sure that the angle and direction of the channels are correct

Poaching

Apart from damage caused by feet, the utilisation of urine and manure is very inefficient once soils are compacted. Cattle are a particular problem but intensive sheep production under brassica crops or high stocking rates during lambing time can all cause soil compaction and poaching.

Under badly poached conditions compacted soils prevent root development and cause ponding after rainfall.

Ponded sites create anaerobic soils which will encourage the loss of nitrogen to the atmosphere in the form of nitrous oxide, a powerful greenhouse gas, over 300 times more potent than carbon dioxide. Other nutrients such as phosphates are lost to the watercourse and organic manures run off the surface.

This movement of soil and nutrients to the watercourse can destroy aquatic life and water can be unfit for consumption.

Vegetation does not recover quickly and the extra seed that is sown to compensate cannot establish itself well.

The impact of poaching can affect soil for many years. Under poached / compacted soil conditions the losses in yield can be considerable.

- **~ 2tonnes of grass growth in terms of DM /ha can be lost on compacted soils**
- **Even under light poaching yield can be reduced by 5-10kgDM/ha/day.**
- **Recovery of applied nitrogen falls from 70% to ~50% when soils are damaged.**

Simple ways to reduce the risk of poaching

- Have multiple gateways to fields and electric fencing facilities
- Outwinter on lighter free draining soils that are well structured
- Provide suitable tracks for moving stock
- Minimise vehicle use (use lighter quad bike type machinery)
- Store silage bales close to where they are fed, but at least 10m from a watercourse
- Use a mobile snacker feeder rather than fixed troughs

When urine becomes toxic...

- Cows deliver around 2L urine to a relatively small area (<0.5m^2) each time they urinate.
- This represents an application rate of 400-1200kg N / ha depending on the feeding regime.
- This amount is toxic to plants unless it can dissipate quickly into the soil.
- **In poached or ponded areas urine cannot dissipate and will burn off and kill the surrounding sward. This can take 12 months to repair.**

Soil management, cross compliance and Glastir

Soil management is required under cross compliance as part of keeping land in Good Agricultural and Environmental Condition (GAEC) and complying with Statutory Management Requirements (SMRs). This aims to improve the agricultural output from soils and reduce the negative impacts on the environment.

Managing soils for cross compliance:

- Understand what activities present the most risk to soils
- Identify and address the risks regularly
- Cross compliance rules are **reviewed** regularly so keep up to date with any changes

Since 2015, it is no longer a requirement to keep a Soil Assessment Record, although it remains good practice to do so. Furthermore leaving rough soil surface no longer counts as minimum soil cover between harvest and 1st March. Soil erosion must be minimised by sowing a cover crop or maintaining a minimum soil cover of crop stubble (GAEC 4). There is also a requirement to limit soil erosion by not undertaking certain operations which may cause physical damage to the soil (GAEC 5), and to protect the soil by maintaining habitats and biodiversity and assessing environmental impact of agricultural intensification projects (GAEC 6). Soil management is, in fact, relevant to all seven of the GAEC standards and to many of the SMRs, in particular SMR 1 (Nitrate Vulnerable Zones (NVZs), which requires an assessment of soil type and nitrogen supply. In addition, SMR 3 (Conservation of Fauna and Flora (Biodiversity)), limits field operations such as, burning, draining, ploughing, harrowing, and fertiliser application, and changes to stocking and stock feeding patterns, which could damage the nature conservation interest of a Site of Special Scientific Interest.

Most activities under grassland farming systems are not significantly high risk when executed under the correct conditions. High risk usually occurs when weather conditions are unsuitable but other factors, such as machinery and stocking densities also have an impact.

High risk activities

- Use of **heavy** machinery such as silage trailers and muck spreaders
- Spreading manures and slurry during **inappropriate** conditions or **in the wrong areas** (surface runoff)

Want to find out more about managing soils to achieve cross compliance?

- **RB209 Fertiliser Manual** – http://www.ahdb.org.uk/projects/CropNutrition.aspx
- **"Think Soils" Manual** – A practical guide to soil assessment © Environment Agency http://adlib.everysite.co.uk/adlib/defra/content.aspx?doc=263232&id=263233
- **The farmers' guide to cross compliance factsheets issued by the Welsh Government are available online at:** http://gov.wales/topics/environmentcountryside/farmingandcountryside/farming/crosscompliance/2015/farmersguidetocrosscompliance/9590471/?lang=en

- Reseeding grassland
- Static feeders/troughs
- **Unrestricted stock access to watercourses** (erosion)
- Grazing when soil is saturated (poaching)
- Out-wintering
- Overgrazing with loss of vegetation cover
- Lack of suitable farm tracks

Glastir

Glastir is Wales' comprehensive agri-environment scheme available to all land managers across Wales. The aim of the Glastir scheme is to protect Wales's natural resources, while also supporting green growth and building resilience within Welsh agriculture and forestry industries, in preparation for a future with a reduced Common Agricultural Policy .

Glastir is the key programme in delivering on the future prosperity and resilience of agriculture and forestry and is the primary delivery model for agri-environment, forestry and climate measures under the next Rural Development Programme 2014-2020. It has a fundamental role to play within our overall approach to the strategic management of our natural resources. The objectives of Glastir are:

- Managing soils to help conserve our carbon stocks and reduce soil erosion
- Improving water quality and reducing surface run-off
- Managing water to help reduce flood risks
- Conserving and enhancing wildlife and biodiversity
- Managing and protecting landscapes and the historic environment
- Creating new opportunities to improve access and understanding of the countryside

The management options available to applicants under Glastir which are designed to meet the objectives of the scheme are underpinned by Cross Compliance requirements.

Glastir Entry – Open to applications from farmers and land managers throughout Wales. It has been designed to support the delivery of general environmental benefits. Successful applicants make a commitment to deliver environmental goods over a 5 years contract.

Glastir Advanced – Designed to deliver significant improvements to the environmental status of a range of habitats, species, soils and water that might also require changes to current agricultural practices. In order to achieve these specific improvements and outcomes, financial support from Welsh government is targeted at locations where actions will lead to the required result.

Glastir Commons – Designed to provide support for the delivery of environmental benefits on common land

Glastir Organic – Provides organic farmers and producers with financial support in recognition of the environmental service they provide to Wales. Organic farming systems work with nature to maintain soil fertility and to manage pests and diseases. This protects our rivers, wildlife and pollinators. Support will be made available both to existing organic producers to carry on farming organically and to those converting land from conventional farming practices to organic.

Glastir: Small Grants – will be developed during the programme. The small grants component will provide support for simple part farm support for small capital works projects to deliver environmental benefit and will include small woodland planting.

Managing soils under forage brassica crops

Extending the season or outwintering on forage brassica crops is an increasingly common practice to reduce production costs.

Growing brassica crops significantly reduces housing costs but there is serious risk of soil damage when grazing forage crops. If site and soil management are poor this can be a costly operation for the farmer, animals and environment. Therefore, before growing a brassica crop, it is essential to first consider if brassicas are right for your farm (climate and soils), whether you have the right field site (gradient, relief and flood risk) for the crop and if there are more suitable alternatives from both an agricultural and environmental standpoint.

Select the site carefully

- Choose fields where grass yields have fallen and a new reseed is required, but minimise poaching, runoff and erosion.

The ideal site will consist of:

- Lighter soils
- Good drainage
- Gentle slopes (<3°)
- Away from watercourses
- Access to more than one water tank
- Multiple access points
- Suited to fencing, positioning of fibre source and runbacks
- Shelter for livestock (hedges, trees).

On heavier soils more care is needed to avoid soil damage.

- Avoid the plough
- Consider direct drilling brassicas into a sprayed off grass sward.

Adapt to the weather conditions

- Heavy rain can cause issues with even the best set up
- Allow stock a larger grazing area to reduce stocking density and poaching
- Consider back fencing higher risk areas of the field to prevent animals worsening the conditions
- Graze slopes from the top down to avoid soil runoff - any soil movement will then be stemmed by the crop.

Plan the grazing regime well in advance – last minute changes can be costly:

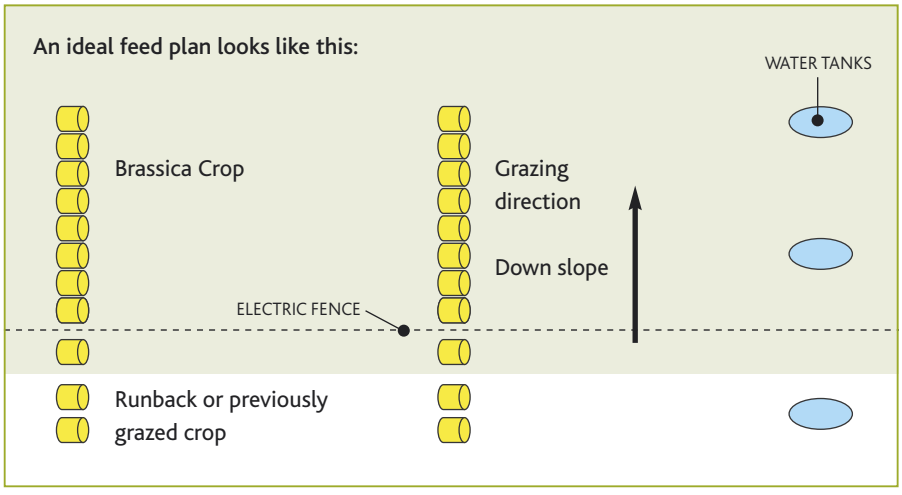
- Create the longest feed face as possible to avoid competition and poaching
- Calculate requirements to provide enough forage in front of livestock
- 25% of feed intake should be fibre (eg straw, hay or haylage) so position this in the field well in advance of grazing
- Avoid using vehicles to carry bales during the grazing period
- Consider leaving a suitably wide headland or unploughed strip through the middle of the field as buffer zones to slow down run-off and trap soil at critical places on a slope or at the bottom of a field.

Managing soils after using brassicas

Once brassicas have been used, the bare field is unprotected from any crop and laden with nutrients from manures. It is also likely to be compacted in many areas. It is important to establish the following crop as quickly as possible.

- Lighter soils should be rough ploughed to prevent capping
- Plough across slope or the bottom of slopes to re direct and slow any water runoff
- Sow the follow-on crop within 10 days of ploughing to get a ground cover established
- A cereal, wholecrop or arable silage crop is a good option – should establish quickly, benefit from the nutrients of manures and avoid the need to introduce stock too quickly onto softened soils.

An ideal feed plan looks like this:



Remember – plan the grazing regime for forage brassicas well in advance - last minute changes can be costly.

Managing soils under maize

More farmers in Wales are exploiting maize as a good source of fibre and energy. This pushes its limits in terms of the altitude, rainfall and soil type in which it is grown. It is an expensive crop to grow and so viability is dictated by the yield that can be achieved.

Maize poses two areas of concern for soils:

- **Sowing –** ground cover is slow to establish after drilling, increasing the risk of surface capping or erosion and runoff. Buffer zones are required all around the field and not just between the crop and a watercourse
- **Harvesting –** the heavy machinery needed to harvest and cart the crop can damage the soil structure. Later season harvesting also reduces the chance to establish a cover crop for the winter and the ground is very susceptible to erosion and sediment runoff
- **Post harvesting –** The land needs to be prepared as a seedbed within 14 days for a crop and the crop must be sown within 10 days beginning with the day after final seedbed preparation.

Soil compaction and the nutrient / water deficit it causes leads to poor root development giving **stunted plants and low yields.**

Even mild compaction has a major impact on crop height and cob development.

Just a 10% increase in soil compaction reduces the rooting depth of maize from 130cm to 35cm creating a 27% loss of yield.

This means a 4.9t/acre yield loss from an 18t/acre crop

At this point the crop is now uneconomical to grow

Impact of maize yield on cost of production

In 2011 the establishment costs for maize production was £900/ha (£400/acre).

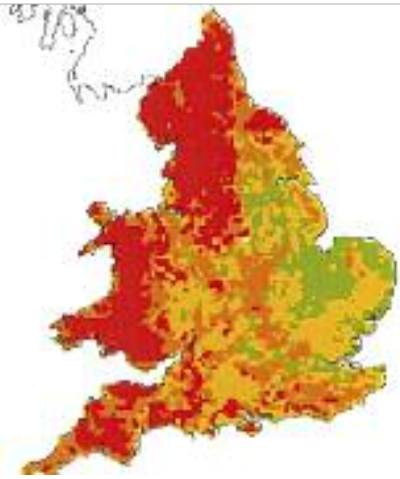
Cost / tonne of dry matter or p/kg of animal liveweight gain is directly affected by yield.

For example, if the yield of maize falls from 18t/acre to 12 t/acre the cost of the crop in terms of its ability to finish beef cattle also increases (see right).

Maize fields are often used as a winter "dumping" area for manures making them high in nutrients and so vulnerable to soil and nutrient loss. This poses large risks for water quality and pollution as well as the financial losses.

Yield (t/acre)	Cost / tonne of utilized DM (15% losses)	Fresh weight (assuming 33%DM)	Utilized DM yield (t/acre)	Beef Cost p/kg LWG (assuming 85 MJ/kg LW)
18	£80	£27	5.1	62p
12	£120	£40	3.4	93p

These figures assume that the Metabolizable energy(ME) content of the crop is = 11.0.



Autumn machinery work days.

Workability ends in September.
Workability ends in October.

Source: Defra

Avoid damaging soils under maize

Most areas of Wales need to be harvested and worked before the end of September.

Sowing

- Avoid growing maize on marginal sites - opt for wholecrop instead
- Sow early or use early maturing varieties so they can be harvested before soils become waterlogged. **Remember that maize sown early possibly under plastic will increase costs and increase run-off**
- Prepare seedbeds carefully to reduce the risk of compaction
- Plant along the contour to reduce any surface runoff
- Don't leave wheelings that can hold water
- **Leave buffer zones between the crop and any watercourse.**

Harvesting

- Harvesting needs to be done when the soils are dry enough
- Avoid using fallow maize ground as a "dumping" area for manures over winter.

Post Harvesting

- The land is prepared as a seedbed within 14 days for a crop and the crop is sown within a period of 10 days, beginning with the day after final seedbed preparation
- Try to sow another crop such as Italian ryegrass to slow surface run off, or consider undersowing the maize in the first place
- Use a chisel plough to break up compaction and work across the slope to slow and re-direct water flow
- Leave a buffer zone to slow water movement and pollution risk
- Do not oversupply nutrients especially manures.

Remember - if yield is not achieved then maize is an uneconomical crop and if land takes a long time to come back into use then costs rise. Consider wholecrop and autumn reseeding as an alternative.

New breeding targets for agriculture and to combat the impacts of climate change

Improved grasslands dominate the Welsh landscape occupying 43% of Welsh lowlands and 26% of Welsh uplands and are potential targets for novel grass and clover varieties currently under development at Aberystwyth University's Institute of Biological, Environmental and Rural Sciences (IBERS) to be later marketed by Germinal.

Due in part to their significant land coverage, grasslands are multifunctional; in addition to providing low-cost, healthy and nutritious forage for livestock they also provide important ecosystem services including their critical role as components of catchments for all major Welsh rivers where they regulate water acquisition, water quality and its later release from soils. Climate change will inevitably lead to changes in agroecosystem functioning. Unprecedented extreme weather patterns impact on the capacity of agricultural grasslands to deliver a range of ecosystem services (e.g. food security, carbon and water storage, biodiversity). These atypical weather events include extreme floods, and prolonged periods of heat stress and drought.

Within a new 5 year project called SUREROOT scientists at IBERS and at Rothamsted Research North Wyke in Devon funded jointly by the Biotechnology and Biological Sciences Research Council (BBSRC) and a large range of industrial partners including HCC are developing new grasses such as *Festulolium* (hybrids between ryegrasses and fescues) and clovers to assist in capture of increased volumes of rainfall, and to thereby to reduce the risk of flooding downstream.

The SUREROOT project builds on earlier BBSRC funded research published in 2013 in the *Nature Journal Scientific Reports* where it was reported that a *Festulolium* variety through its grass root soil interactions instigated a change in soil structure leading to increased water retention with a prolonged and significant 51% reduction in rainfall run off compared with equivalent ryegrasses that were grown alongside and that are currently used extensively throughout the UK.

The project incorporates use of 2 National Capability facilities, the National Plant Phenomics Centre at IBERS where changes in root design and growth will be monitored, and at the Farm Platform at North Wyke where their effects in terms of soil water release are being assessed. Commercial Development Farms representing a wide range of livestock management systems and at diverse UK locations will assess the performance of the new *Festulolium* grasses when under "real-farm" conditions.

BBSRC and industry funded science developing improved rooting systems in grasses and clover for sustainable livestock systems and for ecosystem service.

Managing your soil resources

A healthy, fertile and well managed soil is a livestock farmer's most valuable asset and managing your soil is key to developing and sustaining good productivity as well as protecting it as a resource for the future.

The majority of land in Wales is permanent pasture and so grass-fed livestock systems also have an important role to play in reducing carbon losses from soil.

Knowing the composition and condition of the soils on your farm is crucial.

Top tips for managing your soils

1. **Assess soil texture** – remember that this can change from field to field or even within fields.

2. **Test your soil** – tests are simple to do and the only way to get a good handle on soil nutrient status. The cost of testing can often be repaid in the first hectare of spring application.

3. **Use the test results** to calculate the amount of lime and fertiliser needed to restore the pH and nutrient balance for the crop grown. Choose the right type of lime and fertiliser products to achieve the target levels. Remember that nutrients come from sources other than bag fertilisers including manures, slurries and wastes for agricultural benefit.

4. Don't forget to **include the reserves of nutrients in the soil and the nutrient input from manures** when calculating the amount of fertiliser you need to add - oversupply wastes time and money and damages the environment.

5. **Soil compaction is the biggest single factor that affects production** – applying fertiliser and manures to compacted soils is a waste of time and money. Dig a hole to identify compaction and where it occurs so that you can remedy the problem and avoid the practices that lead to compaction.

6. Remember that whilst brassicas and maize can reduce winter feed costs, **badly managed crops can cost £thousands in long-term losses**.

7. **Soil management is a cross compliance requirement** as part of GAEC (Good Agricultural and Environmental Condition). Understanding the activities that present the most risk to soils is crucial - cross compliance rules are reviewed regularly so keep up to date with any changes.