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# Liming materials and recommendations



National Advice Hub T: 0300 323 0161 E: advice@fas.scot W: www.fas.scot

# **Summary**

- Maintaining optimum acidity status is required to achieve maximum yields. When soils are below target for pH yields will be lower and this should be accounted for as part of your fertiliser management plan.
- Regular soil analysis with accompanying field information is essential to manage lime inputs for optimum yields and profitability.
- There has been a large drop in the number of soil pH samples from 69,062 (1993-1997) to half this during the last 5 years.
- Recent studies have shown that pH levels are declining on grassland farms.
- Liming recommendations for different soils and cropping systems are tabulated.

# Introduction

Soils should be sampled every 4 to 5 years and analysed for soil pH, extractable P, K and Mg. The value of accompanying field information such as FID, and previous and next crop increases the value of any subsequent analysis of data including use of PLANET Scotland, a software tool designed for Scottish farmers and consultants to plan and manage nutrient use on individual fields (http://www.planet4farmers.co.uk).

The optimum availability of most plant nutrients in soil occurs over a small range of soil pH values. Maintaining the optimum pH in the topsoil in all parts of the field is important to achieve optimum yields and consistent quality. Aim for an optimum soil pH of 6.0 to 6.2 on mineral soils. Aim lower at pH 5.3 to 5.5 on peaty soils. Liming materials should be purchased on the basis of the price relative to the neutralising value

and fineness of the products on offer. The fineness will usually include the maximum size of particles and the amount passing a 150 micron sieve. The finer the grinding of the product the more rapid the rate at which neutralisation occurs.

Regional differences in soil acidity exist primarily in response to differences in soil type, land use and particularly the greater role of livestock in the west compared to arable cropping in the east. In this technical note an attempt is made to link soil pH values and extractable magnesium (Mg) in soils with information from the National Soil Database of Scotland initially published in TN656 (2014) (www.fas.scot/publications/technical-notes/).









# Trends in soil pH and Mg advisory data from 1993-2017

#### Number of soil samples

Nationally 225,396 samples have been analysed from 1993 to 2017 for the advisory services. The data have been separated into 4 Regions: 1 – NE Scotland and Tayside; 2 – SE Scotland; 3 – SW Scotland; and 4 – Highlands and Islands (Figure 1). The numbers of soil samples have been split in to the 4 Regions and 5-year intervals in Table A.



Figure 1. Regions: 1 – NE Scotland and Tayside; 2 – SE Scotland; 3 – SW Scotland; and 4 – Highlands and Islands

Years	Region 1	Region 2	Region 3	Region 4	Total	
1993-1997	27866	17154	13209	10833	69062	
1998-2002	<b>98-2002</b> 17864		10528	6982	47555	
2003-2007	<b>003-2007</b> 15331 90		5900	6944	37261	
2008-2012	<b>-2012</b> 13137 7858		9938 6151		37084	
2013-2017	12072	6382	10456	5524	34434	
Total	86270	52661	50031	36434	225396	

Table A. Number of soil samples in each Region and 5-year periods

The number of samples tested during 2013-2017 has dropped to half the number during 1993-1997. The number of samples in the SW region has recovered during recent years and currently is about 80% of those during 1993-1997.

#### **Classification of soil pH values**

Soil pH values have been classified in to 5 classes in Table B. Regions 3 and 4 have significantly more samples with low pH values reflecting the greater role of grassland in the west compared to arable cropping in the east. If soil pH is not corrected by liming soils with pH values of 5.5 and lower, then yield potential is expected to be lower by up to 20% in grass: 30% in winter wheat; and 50% in spring barley even with adequate PK fertiliser. Region 2 has significantly more samples with high pH values probably reflecting more limestone parent material in the SE of Scotland.

Table B. Percentage of soil samples (%) in each pH class nationally and regionally

pH class	<5	5-5.5	5.51-6.25	6.26-7.0	>7.0
Nationally	2.2	13.9	63.7	18.4	1.9
Region 1	1.2	9.7	72.5	16.1	0.7
Region 2	1.1	7.9	56.1	31.7	3.1
Region 3	2.9	23.7	59.5	12.5	1.3
Region 4	5.3	19.1	59.4	12.5	3.7

#### **Classification of soil extractable Mg**

SAC Consulting classifies soil Mg test values extracted by the Modified Morgan's method in to 6 categories (Table C). The percentage of soil samples (%) in each Mg Status nationally and regionally are listed in Table D. Region 2 has more samples with

high Mg Status probably reflecting higher pH values historically in the SE of Scotland and the proximity of magnesian limestone quarries in NE England. There is a trend in Mg status declining from 52% in the H Status in 1993-1997 to an average of 42% during the last 10 years.

Table C. Classification of extractable soil Mg (mg/l) into Mg Status

Mg Status	Very Low (VL)	Low (L)	Moderate (M-)	Moderate (M+)	High (H)	Very High (VH)
Range (mg Mg/l)	<20	20-60	61-100	101-200	201-1000	>1000

Table D. Percentage of soil samples (%) in each Mg Status nationally and regionally

Mg Status	VL L		M- M+		н	VH
Nationally	0.2	8.1	31.1	30.0	30.5	0.2
Region 1	0.4	14.4	39.1 26.2		19.8	0.0
Region 2	0.1	2.5	17.1	33.0	47.2	0.1
Region 3	0.1	4.7	28.9	30.8	35.4	0.1
Region 4	0.3	6.0	35.1	33.2	24.7	0.7

#### Calcium to magnesium ratio (Ca: Mg) of the soil

One common question is if there is a detrimental impact on the structure of clay soils from applying extra magnesium to the soil that is already high in Mg? Calcium can improve soil structure by causing the soil particles to move apart for aeration and drainage. Magnesium makes the particles stick together. The role of these cations on soil structure is described in terms of the Ca: Mg ratio of the soil as it is the balance of the two that has an impact on soil structure. In low Ca clay soils the Mg will have a more dominant effect on structure and can cause the soil to bind together. It is the balance between the two that results in a good structured clay soil. In general if your soil test is showing high Mg Status there is no need to apply more Mg because doing so may also impact soil structure.

It must be noted that most clay soils with severe structural problems that are not due to physical compaction will typically have high amounts of sodium cations attached to the clay as well, causing clay particles to disperse when wet and set like concrete when dry. Sodium is deposited on soils near coasts with predominantly onshore winds. However, sodium is usually washed out of coarse textured soils within 12 months.

The main source of magnesium application to soil is magnesian ground limestone. A magnesian limestone with the minimum

amount of magnesium carbonate will contain 10% Mg (15% MgO) and 26% Ca i.e. a tonne of this magnesian lime will apply 100 kg Mg and 260 kg Ca, a ratio of Ca: Mg of 2.6:1. There has been much research done world-wide on trying to identify soil structural problems associated with cation ratios, most of which does not definitely show benefits to having the "right ratio" of Ca: Mg. Rather than total Ca: Mg ratio in a soil, a better way would be to measure the extractable Ca and Mg in the soil by Modified Morgan's method and take plant tissue samples. Furthermore, using Ca: Mg ratios in isolation can lead to erroneous interpretations as calcium and magnesium levels can both be low, yet have an ideal ratio; or both can be high, yet have an ideal ratio. Although there is no definitive ratio, a ratio of extractable Ca: Mg in clay soils of 4:1 to 7:1 is expected to ensure that Mg is not excessive and detrimental to soil structure and aeration.

High Mg status soil in the SAC soil test starts at an extractable Mg value above 200 mg/l. The extractable Ca level in a heavy soil limed to a target pH value of 6.0 to 6.2 is typically between 1600 and 2400 mg/l i.e. a Ca: Mg ratio of between 8:1 and 12:1. Even where extractable Mg is 400 mg/l, the Ca: Mg ratio is expected to be in the range 4:1 and 8:1.

#### Other sources of magnesium

Potatoes are susceptible to magnesium (Mg) deficiency and may show yield responses to Mg fertiliser on soils where the Mg Status is Very low or Low. Deficiency symptoms are interveinal chlorosis beginning on older leaves, giving a mottled appearance. Symptoms occur early in the growing season when root growth is restricted, for example by soil compaction or cold weather, but they often disappear as the roots grow and thoroughly explore the soil for nutrients. Magnesium deficiency is most severe in dry summers where irrigation is not applied. When early symptoms of Mg deficiency develop, a foliar application of magnesium sulphate (Epsom salts; 16% MgO) at 15-25 kg/ha may be applied in a single dose but each 5 kg should be dissolved in 100 litres water. Other commercial products are available. Label recommendations should not be exceeded.

Symptoms in cereals are leaf margin scorch in semi-circles and a mottled appearance in leaves. Oilseed rape symptoms are interveinal yellowing (marbling) of older leaves often associated with a blotchy reddening or purpling usually seen in early spring during stem extension.

Where soil Mg Status is Very low or Low and soil acidity needs to be corrected, applying magnesian limestone is recommended. An application of 5 t/ha of magnesian limestone will add at least 750 kg MgO/ha, and this Mg will become plant-available over many years. However, if used too frequently, the soil Mg Status can become unnecessarily high. In this situation care should be taken to ensure that there is sufficient available K in soil to ensure that there is no risk of K deficiency in the crop being grown. Where Mg Status is Very low or Low but additional lime is not required, alternative sources of Mg should be used e.g. calcined magnesite (typically 80% MgO) or kieserite (25% MgO). In such cases between 80 and 120 kg/ha MgO should be applied.

## **Choosing liming materials**

To be effective a liming material must be able to react with and neutralise hydrogen ions (H<sup>+</sup>) which are the cause of declining and

low pH soils. Common liming materials contain either calcium or magnesium carbonate  $(CO_3)^{2-}$  or oxide  $(O^{2-})$  which neutralises H<sup>+</sup> and increases the soil pH value. The magnesium and calcium can be beneficial for soil quality and plant nutrition but do not have a direct role in increasing pH value. Materials such as gypsum also contain calcium but not carbonate and will therefore not correct soil acidity.

Liming materials should be purchased on the basis of the price relative to the neutralising value and fineness of the products on offer. Ground limestone consists largely of calcium and magnesium carbonates of which 100% will pass through a sieve of 5 mm, not less than 95% will pass through a sieve of 3.35 mm and not less than 40% will pass through a 150 micron sieve. The finer the grinding of the product the more rapid the rate at which neutralisation occurs. Neutralising value (NV %CaO) is a measure of how much carbonate or oxide is in the product. The higher the neutralising value, the more carbonate is present and the greater its value as a liming material. Table E shows a list of common liming materials and an example of how to determine a rate based on neutralising value can be found at the end of this note. Burnt lime, CaO, does not contain carbonate but reacts in soil to increase soil pH value. Hydrated lime, Ca(OH), is a product obtained by slaking burnt lime or magnesian burnt lime of which not less than 95% will pass through a 150 micron sieve. Fertiliser regulations require calcareous sea shells e.g. scallops, to be pulverised in order that 100% will pass through a sieve with a mesh of 6.3 mm. Calcareous sea sand also requires 100% to pass through a sieve with a mesh of 6.3 mm.

Granulated or prilled lime is usually finely ground calcium or magnesium limestone that has been processed in a similar way as fertiliser making it into a convenient liming product since it is easy to handle and can be spread without the need for specialised equipment. This treatment process does not increase the lime value of the material which means that the same volume of granulated lime is required as the equivalent product in powder form.

Table E. Neutralising values (NV %CaO) of some common liming materials

Material	Typical range of NV values (%CaO)
Ground magnesian limestone	50 – 56
Ground limestone	44 – 55
Burnt lime (or known as Quicklime)	80 – 95
Hydrated lime (or known as Slaked lime)	70 – 72
Lime-stabilised sludge cake	5 – 13
Shell sand	25 – 30
Pulverised shells	45 – 52
Bulk calcified seaweed	44 – 47
Lafarge Redland – <i>pH</i> ASTLIMET <sup>™</sup>	58
G-lime, Granulime, Calciprill and Crop Fertility Pelleted Lime	52 – 54

In addition to slurry and manure, there is an increasing range of waste or waste derived materials such as composts, digestate, and biosolids becoming available for use in agriculture. When assessing their potential liming value it is important to make a distinction between the pH of the material and its neutralising value. Table F shows the pH and neutralising values for a range of organic materials that are commonly spread to land.

Table F. Typical pH range and NV values of some organic materials

Material	Typical pH range	Typical range of NV values (%CaO)*			
Livestock Slurry	6.5 – 7.5	0.9 – 1.3			
FYM	7.9 – 8.1	1.0 – 1.3			
Food-based digestate	7.8 - 8.4	0.9 – 1.2			
Green compost	8.0 - 8.2	1.8 – 2.0			
Paper sludge crumble	6.6 – 7.2	2.0 – 10			

\*NV will vary based on feedstock and dry matter content

Liming value of these materials can vary depending on the feedstock and treatment process and should be tested if applied as a liming material. Green compost and FYM have a high pH but a low neutralising value and therefore should not be considered as liming materials. The liming value of biosolids should be treated as minimal unless it is clearly stated that lime has been added as part of the treatment process.

Once a soil test has confirmed that the field is on target for pH based on its soil type and cropping cycle then ongoing acidity management is still required but should be achieved using the most cost effective products.

# Lime recommendations for different soils

Natural pH of a soil depends on the nature of the parent material from which it was developed, the soil profile age and climatic weathering. In Scotland, extremes of acidity (pH < 4.0) and alkalinity (pH > 7.0) are associated with organic rich (peat) and calcareous parent materials respectively. Most mineral soils fall within the pH range 5 - 6 and as a result of glaciation have a mixed parentage and mineralogy. Typically, the pH of topsoil will be lower than the associated subsoil. For soils with a pH lower than 7, natural processes (e.g. rainfall, crop growth and leaching in drainage water) and farming practices (e.g. use of some nitrogen fertilisers) tend to acidify soil. Acidifying processes can cause soil pH to fall quickly, particularly in sandy soils, and regular pH checks every 4 to 5 years are advisable. If problems are suspected, soil pH should be checked.

At soil pH values below 5.6 in mineral soils in Scotland, soluble aluminium inhibits cereal root growth and reduces yield. Organic soils contain less aluminium and for this reason can be maintained at lower pH values than for mineral soils for any given crop. The aim should be to apply liming material to avoid patches with pH below 5.6 in all parts of the field on mineral soils. For each field, the amount of lime to apply will depend on the current soil pH, soil texture, soil organic matter and the optimum pH needed. Clay and organic soils need more lime than sandy soils to increase pH by one unit. A lime recommendation is usually for a 20 cm depth of cultivated soil or a 7 cm depth of grassland soil. The SRUC soil testing laboratory measures dry soil bulk density along with soil pH in order to assess the lime requirement for each soil sample. Table G gives examples of the recommended amounts of lime (based on a NV of 50% CaO) required to raise the pH of different soil types to achieve the optimum pH level.

Soil pH can vary considerably metre by metre, especially if there is a range in soil textures within fields. GPS sampling for soil pH at 4 samples/ha, each sample containing a number of cores bulked together, and variable lime application can be cost-effective in many fields. Identifying major soil types and yield variation in the field is a key step in establishing the need for GPS sampling. Before embarking on GPS sampling within fields for soil pH:

- Compare crop and variety performances between fields
- Identify and calculate financial loss to the farm of poor output areas
- Identify and remedy soil structural and wetness problems

Where soil is acidic below 20 cm, and soils are ploughed for arable crops, a proportionately larger quantity of lime should be applied. However, if more than 10 t/ha is needed, half should be deeply cultivated into the soil and ploughed down with the remainder applied to the surface and worked in. For established grassland or other situations where there is no, or only minimal, soil cultivation, no more than 7.5 t/ha should be applied in one application. In these situations, applications of lime change the soil pH below the surface very slowly. Consequently the underlying soil should not be allowed to become too acidic because this will affect root growth and thus limit nutrient and water uptake, which will adversely affect yield. Lime should be applied at least 6 months prior to reseeding in order to allow soil pH to increase before sowing, and prior to applying phosphate fertiliser. Applying phosphate and lime in close proximity can lead to phosphate being locked up due to precipitation as calcium phosphate.



Table G. Lime requirement values (t/ha of product with NV 50% CaO) for arable and rotational grassland; and permanent grassland that is ploughed at reseeding

Soil pH	Sands	Sands (S, LS) Sandy loam		loams	Other mir	neral soils	Humose soils		Peaty soils	
	Arable & rot. grass	Perm. grass	Arable & rot. grass	Perm. grass	Arable & rot. grass	Perm. grass	Arable & rot. grass	Perm. grass	Arable & rot. grass	Perm. grass
6.2	0	0	0	0	0	0	0	0	0	0
6.1	0	0	2	0	3	0	0	0	0	0
6.0	2	0	3	0	4	0	0	0	0	0
5.9	2	0	4	0	5	0	2	0	0	0
5.8	3	0	4	0	5	2	3	0	0	0
5.7	4	2	5	2	6	2	4	0	0	0
5.6	4	2	6	3	7	3	5	0	2	0
5.5	5	3	6	4	8	4	6	2	4	0
5.4	5	4	7	4	9	5	7	2	5	0
5.3	6	4	8	5	10	6	8	3	6	0
5.2	7	5	8	6	10	6	9	4	7	0
5.1	7	5	9	6	11	7	10	5	8	2
5.0	8	6	10	7	12	8	11	7	10	4
4.9	8	7	10	8	13	9	12	8	11	5
4.8	9	7	11	8	14	10	13	9	12	6

Where permanent grass is reseeded without ploughing lime requirements may be further reduced. All rates are provided based on a neutralising value of 50% CaO.

## **Example recommendations**

#### Example 1

A ground calcium limestone product with a neutralising value (NV) of 55% CaO is proposed for use on permeant grass field with a pH of 5.6 and a clay texture (other mineral). From Table G the recommendation rate is 3 t/ha based on a product with a NV of 50% CaO.

To find the adjusted rate divide 50 by the NV of the product to be used and multiply this by the recommended rate from Table G.

Adjusted rate = 
$$50$$
 (Neutralising value of CaO) x 3 (Rate from Table G) = 2.7 t/ha  
55 (Neutralising value of lime product)

As the NV of the product to be used is higher the required rate is reduced.

#### Example 2

Shell sand with a NV of 27% is proposed for use on a sandy loam with a pH of 5.7 to support an arable rotation. The recommended rate is 5 t/ha based on a product with an NV of 50%.

$$Adjusted rate = 50 (Neutralising value of CaO) x 5 (Rate from Table G) = 9.3 t/ha$$

$$27 (Neutralising value of lime product)$$

As the NV of the shell sand is lower a higher rate is required.

#### Authors:

Bill Crooks, SAC Consulting, Auchincruive, Ayr, KA6 5HW Tel: 01292 525377 Alex Sinclair, SAC Consulting, Craibstone Estate, Aberdeen, AB21 9YA Tel: 07776 486 966 Tony Edwards, SRUC, Ferguson Building, Craibstone Estate, Aberdeen AB21 9YA, Tel: 01224 711097 A Gay is acknowledged for the advisory soil test data; and S Dolan for proof reading.