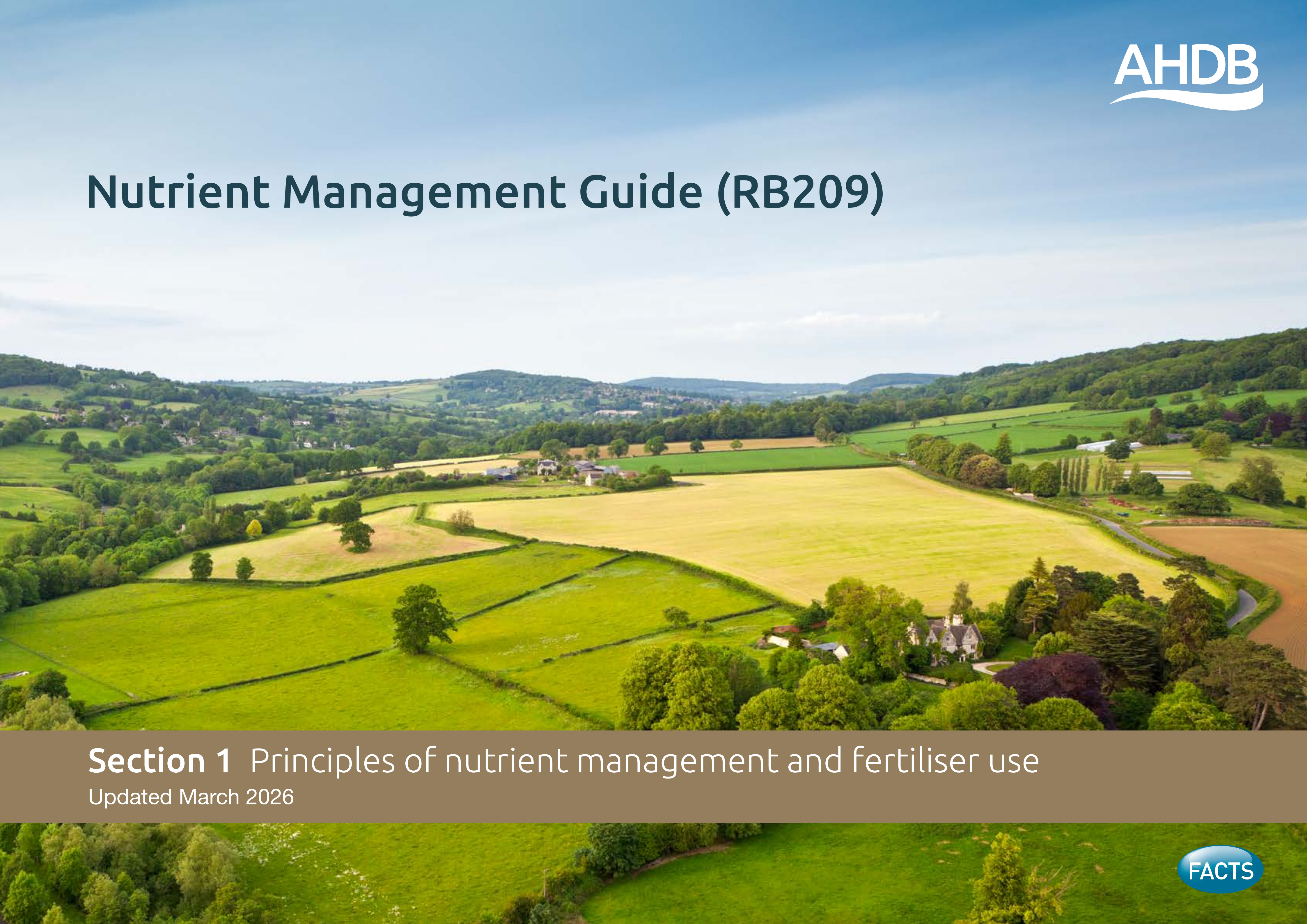

Nutrient Management Guide (RB209)

Section 1 Principles of nutrient management and fertiliser use

Updated March 2026

Contents

Using the Nutrient Management Guide (RB209)

The Nutrient Management Guide (RB209) is funded and supported by the Agriculture and Horticulture Development Board in conjunction with a range of industry and academic partners. AHDB first published the Nutrient Management Guide (RB209) in May 2017, after taking over secretariat and governance for revisions from Defra in November 2014. Since its publication, recommendations have been revised using the latest independent research funded by AHDB and its partners. A list of updates is available at **ahdb.org.uk/rb209**

To improve the accessibility and relevance of the recommendations and information, the Nutrient Management Guide (RB209) is published as seven sections that are updated individually:

- Section 1: Principles of nutrient management and fertiliser use
- Section 2: Organic materials
- Section 3: Grass and forage crops
- Section 4: Arable crops
- Section 5: Potatoes (content last updated 2021)
- Section 6: Vegetables and bulbs (content last updated 2021)
- Section 7: Fruit, vines and hops (content last updated 2017)

This section (**Section 1**) provides guidance on good nutrient management, as well as basic principles of crop nutrition, soils and fertiliser products and application. **Section 1** should be read together with **Section 2** and the section(s) most relevant to your farming enterprise.

Further information

For Scotland, Technical Notes on fertiliser recommendations relevant to Scottish soils are available via the Farm Advisory Service **fas.scot/technical-notes**

The Nutrient Management Guide (RB209) supports our farmers, growers and their trusted advisers to make the most of organic materials and balance the benefits of fertiliser use against the costs – both economic and environmental. The guide outlines the value of nutrients and soil and explains how good nutrient management can save money and infer improved environmental outcomes. The guide aims to increase the uptake and accuracy of crop nutrient management planning.

Disclaimer

While the RB209 guidance may help to inform assessments of pollution prevention and control under national regulations, the Nutrient Management Guide (RB209) was not directly developed, nor peer reviewed, for this purpose. It should not be relied upon as the sole source of nutrient management guidance for informing environmental assessments.

AHDB and its partners shall not be held liable for any misuse of the Nutrient Management Guide (RB209) by anyone. All users are responsible for their application of the information within the guide.

Always consider your local conditions and consult a FACTS Qualified Adviser if necessary.

The basis of good practice

Practices that make the best economic use of nutrients also help protect the wider environment.

Obtain relevant information:

- Soil type
- Field cropping, fertilising and manuring history every 3–5 years
- Regular soil analysis for pH, P, K and Mg
- Nutrient balances – surplus or deficit from applications to previous crops
- An assessment of soil nitrogen supply every spring before applying nitrogen fertiliser
- Winter rainfall
- Crop tissue analysis where appropriate

Assess crop yield potential, economics and markets:

- Take account of fertiliser nitrogen and crop produce prices
- Consider market requirements for quality and quantity of harvested produce
- Adjust phosphate and potash for expected crop yield (including straw where removal is planned)

Assessment of available nutrients from organic materials:

- Apply manures in spring if possible and incorporate rapidly into the soil following surface application to tillage land or use of trailing hose, trailing shoe or injection equipment for slurry
- Make use of manure analysis (on-farm and laboratory testing) or use of standard values (**Section 2: Organic materials**)
- Calculate available nutrients based on manure type, method and time of application

Further information

Read what to record in a nutrient management plan.
ahdb.org.uk/nutrient-plans

Decisions on the rate, method and timing of fertiliser application for individual crops:

- Apply nitrogen when there is greatest demand for it
- Consider placement of fertilisers for responsive crops

Careful selection of fertilisers:

- Consider the cost-effectiveness of alternative fertiliser materials
- Take account of the nutrient percentage and the availability of nutrients for crop uptake
- Make sure that the physical quality of the fertiliser will allow accurate spreading

Accurate application of fertilisers and manures:

- Regularly maintain and calibrate fertiliser spreaders and sprayers
- Regularly check and maintain manure spreaders

Record-keeping:

- Keep accurate field records to help with decisions on fertiliser use

Points to consider

- Statutory rules that affect nutrient use apply in all parts of the UK. Nitrate Vulnerable Zone (NVZ) rules apply in England and Scotland, and there are similar rules in Wales
- Also in England, Farming Rules for Water cover nutrient use generally but particularly the use of nitrogen and phosphate
- In Northern Ireland, Nutrient Action Programme (NAP) rules affect both nitrogen and phosphate use
- All relevant rules should be consulted at an early stage in nutrient management planning to ensure compliance. There can be closed periods and limitations on the amounts of nitrogen and phosphorus applied in manufactured fertilisers and organic manures

Good nutrient management

This guide helps farmers and advisers to make the most of organic materials and balance the benefits of fertiliser use against the costs – both economic and environmental. It explains the value of nutrients and soil, and why good nutrient management is about more than just the fertilisers you buy. Nutrient management can save you money as well as help protect the environment. To help your forward planning, the guide also outlines possible future changes that could further affect fertiliser use.

The growing challenges

The agricultural sector faces a number of challenges, including producing more food to feed a growing population while impacting less on the environment. Agricultural production relies on environmental resources, such as soil, water and air, and is vulnerable to climate change, including flood and drought. Good nutrient management using a balanced long-term approach is part of a sustainable agricultural system that is resilient to climate and economic change.

Sources of inorganic nutrients are limited, and manufacture of fertilisers requires energy, so recycling of nutrients through the use of organic materials and improving nutrient availability from well-structured, biologically active soils make better use of resources and economic sense.

Ensuring the carefully managed application of all nutrients, including manufactured fertilisers and organic materials, helps to close the 'nutrient gap' that arises when the crop is removed at harvest. Optimising nutrient uptake by crops helps minimise an excess in the soil where, for example, nitrogen can be lost as nitrous oxide or ammonia to the air or nitrate to water.

Demand for land to grow non-food crops, such as biomass crops, and from non-farming uses may well increase. This is one factor which may mean that higher crop yields will be necessary to supply the increased demand for food.

Greenhouse gases

At present, agriculture is estimated to contribute around 9% of total UK greenhouse gas emissions. An estimated 70% of the UK's nitrous oxide emissions – a greenhouse gas around 300 times more potent than carbon dioxide – comes from agriculture. Soil nitrous oxide emissions come from three on-farm sources: grazing returns, storage and application of organic manures and nitrogen fertiliser.

Careful planning, paying particular attention to soil pH that maximises the efficiency of fertiliser use and better management of manures, can help reduce the amount of nitrogen that is lost as nitrous oxide. The farming industry has published its Greenhouse Gas Action Plan, which confirms its intent to play its part in helping to reduce greenhouse gas emissions.

Further information

Reducing emissions on farm
ahdb.org.uk/reducing-emissions

Protecting our Water, Soil and Air: A Code of Good Agricultural Practice for farmers, growers and land managers
gov.uk/government/publications/protecting-our-water-soil-and-air

Carbon footprint calculators
ahdb.org.uk/carbon-calculators

Water quality

Farming is one of many influences on water quality and water-dependent ecosystems. The main agricultural pollutants are nutrients (phosphates and nitrates), pesticides and other agrochemicals, faecal bacteria and sediment. Losses from the application of manufactured fertilisers and spreading of organic manures contribute to diffuse water pollution.

In England and Wales, around 60% of nitrates and 25% of phosphates in our waters originate from agricultural land. Elevated levels of these nutrients can harm the aquatic environment and have an impact on biodiversity. In addition, excessive amounts of agricultural pollutants, including nitrates and phosphates, have to be removed before water can be supplied to consumers.

The Water Framework Directive requires our rivers, lakes, ground and coastal waters to reach or maintain good ecological and chemical status. Therefore, it is important that agricultural land is managed carefully to avoid losses of soil, nutrients and faecal bacteria.

Key measures to reduce the risk of phosphate movement to water include:

- Avoiding build-up or maintenance above the target Index
- Following the recommendations in this guide to maintain the target level of crop-available soil phosphate, taking full account of the phosphate content of organic materials applied (**Section 2: Organic materials**)
- Minimising the risk of soil erosion
- Avoiding surface applications of inorganic fertilisers and organic manures (solid or liquid) when soils are snow-covered, frozen hard, waterlogged, deeply cracked or on steeply sloping ground adjacent to watercourses
- Applying inorganic fertiliser in small amounts as annual dressings, rather than as a single, large dressing. Large applications of both organic materials and inorganic fertilisers aimed at increasing the Soil Index should be thoroughly mixed in the soil

Soils

Incorporating organic materials (e.g. composts, manure and biosolids) plays an important role in increasing levels of organic matter in soil. It can have important agricultural and ecological benefits, such as reducing fertiliser requirements, improving soil condition and biological activity and diverting materials from landfill.

Certain materials spread on land can also contain low concentrations of pollutants, especially heavy metals, which, following repeated applications, can accumulate in the soil. This could pose a risk to human health and the environment. Remediating soils which contain pollutants is difficult and costly, so it is important to prevent unacceptable levels of pollutants getting into the soil.

Further information

AHDB Field drainage guide
ahdb.org.uk/drainage

thinksoils
ahdb.org.uk/thinksoils

AHDB Nutrient Management Guide (RB209) Section 2: Organic materials
ahdb.org.uk/rb209-section2

Air quality

Agricultural activities account for around 90% of ammonia emissions. High concentrations of ammonia in the air can mean that nitrogen is deposited from the air onto the land. This can damage some habitats by changing the species of plants present and pollute streams, rivers and other water bodies. The ammonia can also be converted to nitrous oxide – a potent greenhouse gas – and released from soils. Ammonia also combines with other substances in the air to form fine particles, which can harm human health.

There are strong pressures to reduce ammonia emissions from agriculture. Large pig and poultry farms are already covered by environmental permitting regulations and there may be controls on a wider range of farms in the future.

The UNECE Gothenburg Protocol and the National Emissions Ceiling Regulations (2018) have been implemented to control ammonia emissions (among other pollutants) at the national level. Both the protocol and the regulations have national emission reduction commitments from 2020, with more stringent commitments from 2030.

Several measures can be used to decrease the ammonia emissions from agricultural activities, e.g. effective manure management from collection and storage to application to land. Substantial reduction in ammonia emissions from slurry and digestate applications can be achieved through injection, trailing-shoe and trailing-hose techniques, when compared with splash-plate or broadcast application methods.

Further information

Livestock actions to reduce emissions
ahdb.org.uk/livestock-actions-to-reduce-emissions

Code of Good Agricultural Practice for reducing ammonia emissions
gov.uk/government/publications/code-of-good-agricultural-practice-for-reducing-ammonia-emissions

Code of Good Agricultural Practice guidance on reducing ammonia losses from agriculture in Wales
gov.wales/sites/default/files/publications/2019-04/code-of-good-agricultural-practice-guidance-on-reducing-ammonia-emissions.pdf

Crop nutrient requirements

In addition to carbon (C), hydrogen (H) and oxygen (O), there are 13 known elements that are essential for plant growth and they can be divided into two groups:

- Macronutrients – nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulphur (S) are required in relatively large amounts
- Micronutrients (trace elements) – iron (Fe), copper (Cu), manganese (Mn), zinc (Zn), boron (B), molybdenum (Mo) and chlorine (Cl) are required in smaller amounts than the macronutrients

The names macronutrient and micronutrient do not refer to relative importance in plant nutrition. A deficiency of any one of these elements can limit growth and result in decreased yield and less efficient use of other nutrients.

It is, therefore, important to ensure there is an optimum supply of all nutrients. For example, if a plant is seriously deficient in potassium, it will not be able to fully utilise any added nitrogen and reach its full potential yield; any unutilised nitrogen may be lost from the field.

In the UK, the following two conventions are used:

- For fertiliser contents and recommendations, phosphorus is expressed in the oxide form, phosphate (P_2O_5), and potassium as potash (K_2O). Sulphur, magnesium and sodium are also expressed in oxide forms (SO_3, MgO and Na_2O)
- Soil and crop analysis reports usually show elemental forms, for example mg P/kg or mg K/l

Timing nutrient application correctly is as important as applying the right amount. Crop demand varies throughout the season and is greatest when a crop is growing quickly. Rapid development of leaves and roots during the early stages of plant growth is crucial to reach the optimum yield at harvest, and an adequate supply of all nutrients must be available during this time.

The amount of a nutrient taken up by a crop may exceed the amount that will be removed in the crop at harvest. For example, at its peak, a high-yielding cereal crop may have taken up the equivalent of 300 kg/ha K_2O, but less than half of this amount may be removed in the grain plus straw at harvest.

Excess application of nutrients, or application at the wrong time, can reduce crop quality and cause problems such as lodging of cereals or increases in foliar pathogens. Excessively large amounts of one nutrient in a readily plant-available form in the soil solution may also decrease the availability or uptake of another nutrient by the root.

Other elements found in plants, which may not be essential for their growth, include cobalt (Co), nickel (Ni), selenium (Se), silicon (Si) and sodium (Na).

Sodium has a positive effect on the growth of a few crops, e.g. sugar beet. Some elements, such as cobalt, iodine (I), nickel and selenium, are important in animal nutrition and are normally supplied to the animal via plants and through supplementary feeds. Therefore, it is important that they are available in the soil for uptake by plant roots.

All these elements are taken up by plant roots from the supply in the soil solution (the water in the soil). They are absorbed in different forms, have different functions and mobility within the plant, so cause different deficiency, or, very occasionally, toxicity effects and symptoms.

Further information

Webinar: Trace elements in beef and sheep production
AHDB Beef & Lamb YouTube channel

Integrated plant nutrient management

Crops obtain nutrients from several sources:

- Mineralisation of soil organic matter (all nutrients)
- Deposition from the atmosphere (mainly nitrogen and sulphur)
- Weathering of soil minerals (especially potash)
- Biological nitrogen fixation (legumes)
- Application of organic materials (all nutrients)
- Application of manufactured fertilisers (all nutrients)

For good nutrient management, the total supply of nutrients from all these sources must meet, but not exceed, crop demand. Crop demand varies with species (and sometimes variety of the crop), yield potential (this in turn depends on soil properties, weather and water supply) and intended use (e.g. feed wheat).

Nutrients should be applied as organic materials or fertilisers if the supply from other sources fails to meet crop demand. Where nutrients are applied, the amounts should be just sufficient to bring the total supply to meet crop need. However, in some cases, it might be appropriate to build the Soil Index and that will require the application of more fertiliser than crop demand.

Recommendation methods used in this guide allow the user to take account of all sources of nutrients, maximising economic return and minimising costly nutrient loss to water and air.

Information in this guide can be used to develop a whole-farm nutrient management plan to make the best cropping choices and use of resources across the farm throughout the rotation. It can be used to make the most of on-farm nutrient supply in soil and organic manures, as well as bought-in nutrient inputs, such as fertiliser, feed and organic manures. Planning cropping and grass rotations (including cover cropping and the use of legumes), incorporating soil, nutrient, manure and crop management over several years can help build soil fertility and reduce reliance on purchased inputs.

Important soil properties

Soil texture

Knowledge of the soil type in each field is important for making accurate decisions on lime and fertiliser use. Assessment of topsoil texture is essential to determine lime requirement; both topsoil and subsoil textures are needed to determine soil-retention properties and associated nitrogen and sulphur recommendations.

Without this knowledge, it is not possible to use the recommendations in this guide effectively. Time is well spent, therefore, in acquiring this information because it is an intrinsic property of the soil that does not change with time.

In this guide, soil type is related to soil texture. Soil texture is defined by the proportion of sand-, silt- and clay-sized mineral particles in the soil and can be determined in a number of ways:

- Assessment of texture by hand using the method described in Figure 1.1 (page 9)
- Laboratory analysis of the proportion of the different mineral particles in the soil, followed by classification using the texture triangular diagram given in the Think soils guide
- Use of the UK Soil Observatory (UKSO) map viewer gives access to a United Kingdom soil properties map
- Soil series for a field can be identified from the National Soil Map for England and Wales, with classification from the accompanying Brown Book (available from the National Soil Resources Institute at Cranfield University) or regional bulletins. Soil series scale maps or soil inspection will be needed to determine soil type

Further information

UK Soil Observatory
ukso.org

Soil data for England and Wales
landis.org.uk

Assessment of soil texture

1. Take about a dessert spoonful of soil.
2. If dry, wet up gradually, kneading thoroughly between finger and thumb until soil crumbs are broken down.
3. Enough moisture is needed to hold the soil together and to show its maximum stickiness.
4. Follow the paths in Figure 1.1 to determine the texture.

Further information

How to determine soil texture
ahdb.org.uk/soil-texture

thinksoils
ahdb.org.uk/thinksoils

GREATsoils
ahdb.org.uk/greatsoils

Soil structure

To achieve optimum economic yields, crops have to acquire sufficient nutrients and water from the soil via the roots. It is, therefore, important to maintain good soil structure so that root growth is not adversely affected by poor physical soil conditions such as compaction.

Soil mineral particles can be aggregated together and stabilised, either by clay or organic matter, to form crumbs. Within and between these crumbs are pores (voids) that can be occupied by air or water, both of which are required for roots to function properly.

If the diameter of the pores is too small, root tips cannot enter and roots cannot grow to find water and nutrients. If pores are too large, water drains rapidly from the soil and roots will not grow because the soil contains too little moisture.

The aggregation of soil mineral particles defines soil structure. For example, sands are often without any recognised structure, while loamy soils can have an excellent one. Developing and maintaining a good soil structure depends greatly on good soil management, including cultivation at appropriate times and depths and minimising traffic over the soil when it is too wet.

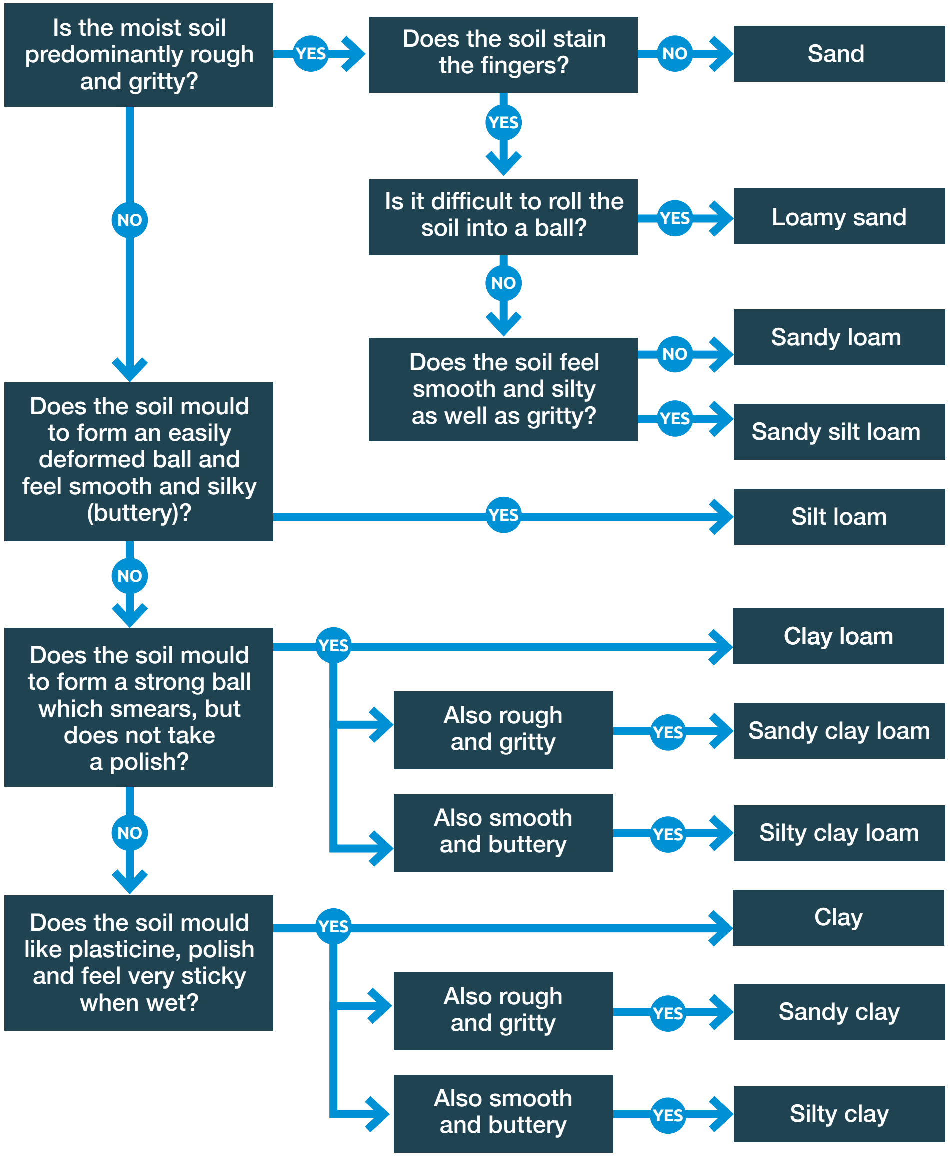

Figure 1.1 Assessment of soil texture by hand

Soil organic matter

Soil organic matter helps bind soil mineral particles of sand, silt and clay into crumbs. It has a number of important functions in crop nutrition, such as:

- Improving soil structure, enabling roots to grow more easily throughout the soil to find nutrients
- Holding phosphorus and potassium ions (the forms taken up by roots) very weakly so that they are readily available for uptake by roots
- Holding a store of organic forms of nitrogen, phosphate and sulphur from which available forms of these nutrients are released by microbial action

The amount of organic matter in a soil depends on the farming system, the soil type and climate. The interplay between the first two factors is that, in general, for the same farming system, a clay soil holds more organic matter than a sandy soil and, for the same soil type, a grassland soil holds more organic matter than an arable soil.

It is difficult to define a critical level of soil organic matter because there are so many combinations of soil type and farming system. However, maintaining and, where possible, increasing soil organic matter should be a priority.

Soil organic matter can be improved by applying bulky organic manures, such as green compost and farmyard manure, and, over the longer term, by incorporating green manures and cover crops into rotations.

Further information

Soil organic matter
ahdb.org.uk/organic-matter

Soil mineral matter

The types of mineral matter in a soil affect the reserves of plant nutrients and their availability. For example, a soil containing minerals from igneous sources is likely to contain more potash and iron than a chalky soil, which will contain more calcium. Soils overlying chalk are typically alkaline (pH above 7), while those overlying sandstone are typically acidic.

Stone content and rooting depth

A large content of impermeable stones increases the speed of water movement through the soil and because there is less fine soil to hold nutrients, the availability of water and nutrients is lower than in largely stone-free soils.

Soil rooting depth is important and many crops have root systems with the potential to grow to a metre deep or more. In deep friable soils where roots can grow to depth, they can take up water and nutrients leached from the surface soil. Shallow soils over hard rock and compacted soil layers limit root growth, restricting nutrient and water availability and limiting crop yields.

Soil acidity and liming

Soil pH is a measure of acidity or alkalinity; it is a logarithmic scale, where pH 6.0 is 10 times more acidic than pH 7.0. Maintaining the right soil pH is essential: poor pH management and lack of attention to liming reduces nutrient efficiency, lowers yields and increase costs, while over-liming may trigger trace element deficiencies and faster lime losses. Good soil pH management can also reduce nitrous oxide emissions.

The pH range for optimum availability of most plant nutrients (Figure 1.2) varies somewhat between types of crops and is lower on high organic matter soils. In acid soils, plant nutrition is impaired where macronutrients N, P and K are not readily available to be taken up by the plant. The optimum pH for each soil type and cropping system is shown in Table 1.1.

Soil pH can be measured in the laboratory using a soil sample taken from the field or directly in the field using a soil test kit. When determined in the laboratory, pH is usually measured in a soil/water suspension. The natural pH of a soil depends on the nature of the material from which it was formed. It ranges from about pH 4 (very acidic), when most crops will fail, to about pH 8 for soils naturally rich in calcium carbonate (lime) or magnesium carbonate.

For soils with a pH below 7, natural processes (e.g. rainfall, crop growth and leaching of calcium in drainage water) and some farming practices (e.g. use of some nitrogen fertilisers) tend to acidify soil. Acidifying processes can cause soil pH to fall quite quickly, and regular pH checks are advisable. Such acidifying processes rarely affect the pH of calcareous soils, except perhaps in the top few centimetres where the soil is undisturbed. If problems are suspected, soil pH should be checked.

Soil pH can vary considerably metre by metre. Maintaining the mean pH in each field or 5 ha block at the optimum level should avoid patches that are well below target (e.g. below pH 5.6 on mineral soils), thereby maintaining crop yield and quality.

Alternatively, in variable fields, Global Positioning System (GPS) sampling for soil pH, combined with variable-rate lime application, can be cost-effective. Identifying major soil types and yield variation in the field is a key step in establishing the need for GPS sampling.

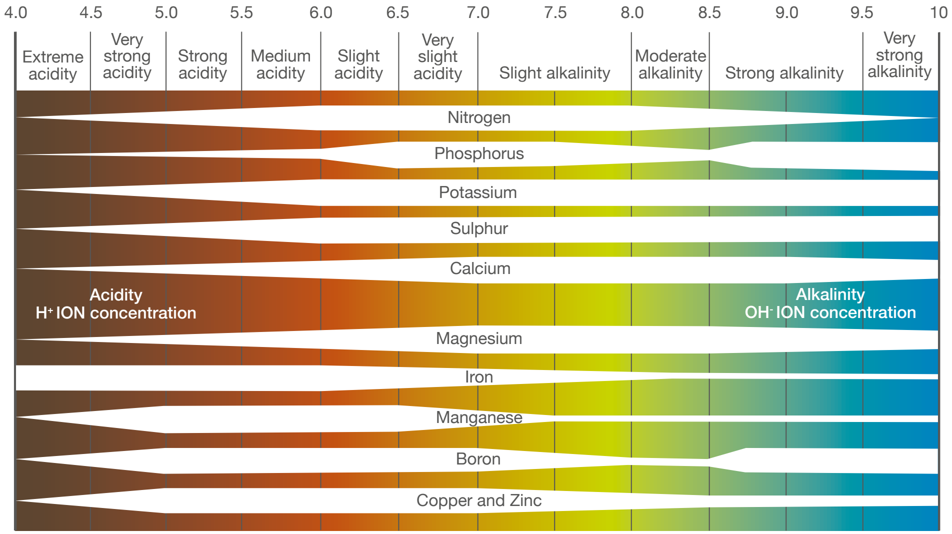

Figure 1.2 Optimal nutrient availability at a range of pH

Table 1.1 Optimum soil pH[a]

Cropping system	Mineral soils	Peaty soils	Organic	Subsoil
Continuous arable cropping	6.5[b]	5.8	6.2	6.3
Grass with an occasional barley crop	6.2[c]	5.5	5.7	6.0
Grass with an occasional wheat or oat crop	6.0[c]	5.3	5.5	5.8
Continuous grass or grass-clover swards	6.0[c]	5.3	5.7	5.8

a. The optimum pH is based on soil that has been correctly sampled. In some soil samples containing fragments of free lime, analysis of the ground-soil sample in the laboratory can give a misleadingly high value for pH.

b. In arable rotations, maintaining soil pH between 6.5 and 7.0 is justified if you are growing acid-sensitive crops such as sugar beet.

c. Where clover is important, lime to pH 6.5.

Lime recommendations

For each field, the amount of lime to apply will depend on the current soil pH, soil texture, soil organic matter and the target pH, which should be 0.2 pH points above optimum (Table 1.1, page 11). 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 15 cm depth of grassland soil.

Table 1.2 gives examples of the recommended amounts of lime (t/ha of ground limestone or chalk, neutralising value (NV) 50–55) required to raise the pH of different soil types to achieve the target pH level shown in the footnotes.

Table 1.2 Lime recommendations in terms of tonnes of lime (NV50) to apply per hectare

Soil type		Liming factor	Liming recommendation (t/ha)			
			Initial soil pH 6.2	Initial soil pH 6.0	Initial soil pH 5.5	Initial soil pH 5.0
Sands and loamy sands[a]	Arable	6	3	4	7	10
	Grass	4	0	0	3	5
Sandy loams and silt loams[a]	Arable	7	4	5	8	12
	Grass	5	0	0	4	6
Clay loams and clays[a]	Arable	8	4	6	10	14
	Grass	6	0	0	4	7
Organic soils[b]	Arable	10	2	4	9	14
	Grass	7.5	0	0	3	7
Peaty soils[c]	Arable	16	0	0	8	16
	Grass	12	0	0	0	6

a. For mineral soils, the target soil pH is 6.7 for continuous arable cropping and 6.2 for grass.

b. For organic soils, the target soil pH is 6.4 for continuous arable cropping and 5.9 for grass.

c. For peaty soils, the target soil pH is 6.0 for continuous arable cropping and 5.5 for grass.

To estimate the lime recommendation (in t/ha of ground limestone or chalk), multiply the liming factor for each soil type and land use combination by the difference between the initial (measured) and target soil pH (0.2 above the optimum pH in Table 1.1):

Lime requirement = (Target pH – Actual pH) x Liming factor land use combination (Arable or Grass from Table 1.2)

The amount of lime needed to correct any subsoil (20–40 cm) acidity can be calculated using optimum pH values in Table 1.1 and liming factors of 5 for arable land or 4 for grassland.

Further information

For information on liming recommendations for Scottish soils, see Technical Note TN714
fas.scot/publications

Liming materials

Liming materials in the UK are regulated under the Fertilisers Regulations 1991, which list 24 recognised materials, including natural quarried limes, burnt and hydrated limes, silicate lime, seashells and lime sand, and industrial limes.

The effectiveness of a liming material depends on its neutralising value (NV), its fineness of grinding and the hardness of the parent rock. The NV is the relative effectiveness of a liming material compared with that of pure calcium oxide (CaO). Lime recommendations are usually given in terms of ground limestone or ground chalk (NV 50–55), but other liming materials can be used, provided allowance is made for differences in NV, fineness of grinding (which affects the speed of reaction in the soil) and cost. The reactivity of a product is the speed at which it neutralises acidity. The finer and purer the product, the greater the surface area exposed to the soil and therefore the more reactive it will be.

The application rate is adjusted to take account of differences in NV. The Fertilisers Regulations 1991 give details of the meaning and required declarations of different named liming products. In addition, materials such as sugar beet lime and lime-treated sewage cake contain useful amounts of lime.

The cost of different liming materials can be compared by calculating the cost per unit of NV, but allowance should also be made for any differences in particle fineness.

Some liming materials contain other useful nutrients, which should be taken into account when deciding which to use. For example, magnesian limestone (dolomitic limestone) contains large amounts of magnesium and is effective for correcting soil magnesium deficiency as well as acidity. However, many years of using magnesian limestone can result in an excessively high soil Mg Index, and excess magnesium in the soil solution may induce potash deficiency in crops.

Example 1.1
Ground limestone has an NV of 50 and costs £20/t delivered and spread. An alternative liming material (A) has an NV of 30 and costs £17/t delivered and spread.

Ground limestone costs (20 x 100) / 50 = 40 pence per unit of NV.
Liming material A costs (17 x 100) / 30 = 57 pence per unit of NV.

Provided the two materials have the same physical characteristics, the ground limestone is the more cost-effective liming material.

Further information

AgLime Quality Standard (AQS)

- Guarantees the regulatory quality of AQS-certified agricultural liming products on the UK market
- Provides clear, concise and independent analysis and certification

aglime.org.uk

Agricultural Lime – The Natural Solution
aglime.org.uk/library

Point to consider

Make allowance for the neutralising value (NV) of the liming material being used, as well as fineness of the material, which affects speed of reaction. Refer to Analysis of fertilisers and liming materials (page 34) for values.

Lime application

It is important to maintain the appropriate soil pH for the cropping system and soil type, and soil pH should not vary by more than ± 0.5 pH unit from the optimum. However, the timing for applying lime can be fitted in with the crops being grown. For example:

- Sugar beet and barley are sensitive to soil acidity; when needed, lime should be applied before these crops are grown
- Clover is more sensitive to soil acidity than many grass species and soil pH should be maintained to encourage a clover-rich sward
- Potatoes can tolerate a degree of soil acidity and are best grown at soil pH levels that are lower than for most other arable crops. Liming immediately before potatoes should be avoided unless the soil pH is very low

A liming material should always be well worked into the cultivated soil because it can take some months to increase pH throughout the topsoil. It is unwise to grow a crop which is sensitive to acidity immediately after liming a very acidic soil. If it is important to try to achieve a rapid correction in the soil surface, then top-dress with a fast-acting lime. In stony soils, lime rates can be reduced, e.g. if stones comprise 20% of the soil volume, reduce lime rate by 20%.

For established grassland or other situations where there is no, or only minimal, soil cultivation, no more than 7 t/ha of agricultural lime should be applied in one application, with the balance applied in the following year.

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.

On arable land, where application rates of over 10 t/ha are necessary lime should be applied as two dressings, with the first dressing ploughed in.

When correcting subsoil acidity on arable land, lime can be ploughed down before the main lime application or applied in the following season. For grassland, the amount of lime needed to correct subsoil acidity can be added to the main application.

Maintenance and top-up applications to address lime losses, crop offtake and other acidifying factors can be readdressed with applications of finely ground granular and sugar beet lime to maintain the mean soil pH.

Nitrogen for field crops

Most agricultural soils contain too little naturally occurring plant-available nitrogen to meet the needs of a crop throughout the growing season.

Supplementary nitrogen applications are normally made each year to meet crop demand. Applying the correct amount of nitrogen at the correct time is an essential feature of good crop management.

Crop nitrogen requirement

The crop nitrogen requirement is the amount of nitrogen that should be applied to give the on-farm economic optimum yield. Nitrogen recommendations for all arable crops in this guide are defined in this way. Crop nitrogen requirement should not be confused with crop nitrogen demand, i.e. the total supply of nitrogen (including that from the soil) that is needed by the crop.

Basis of the recommendations

Provided there are adequate supplies of water and other nutrients, nitrogen usually has a large effect on crop growth, yield and quality. Example 1.2 shows a typical nitrogen response curve. Applying nitrogen gives a large increase in yield, but applying too much can reduce yield by aggravating problems such as lodging, foliar diseases and poor silage fermentation.

When too much nitrogen is applied, a larger proportion is unused by the crop. This is a financial cost and can also increase the risk of nitrogen losses to water and air.

At nitrogen rates up to the on-farm economic optimum, there is a roughly constant amount of nitrogen left in the soil at harvest. At nitrogen rates above the on-farm economic optimum, there will be a larger surplus of residual nitrogen, usually as nitrate, in soil after harvest. This nitrate is at risk of loss, which can cause environmental problems like leaching to ground or surface water and denitrification to nitrous oxide (a greenhouse gas).

Further information

Nitrogen fertiliser adjustment calculator for cereals and oilseeds
ahdb.org.uk/nitrogen-calculator

Cost-benefit calculator for nitrogen fertiliser use on grassland
ahdb.org.uk/nitrogen-calculator-grass

Example 1.2

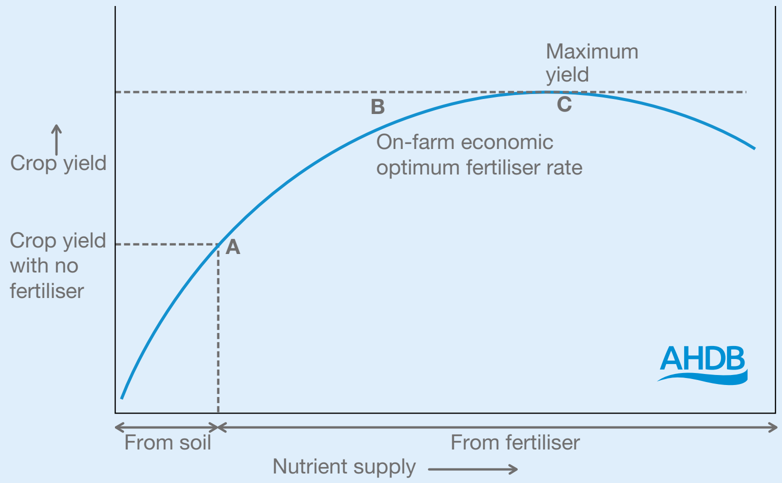

Figure 1.3 A typical nitrogen response curve

Without applied nitrogen, yield typically is low (A).

As nitrogen use increases from very small amounts, there is a large increase in yield up to the on-farm economic optimum nitrogen rate (B). This rate depends on the cost of the applied nitrogen and on the value of the crop (break-even ratio), as well as on the shape of the response curve.

Recommendations for cereals and oilseeds are calculated using a typical break-even ratio to provide the best on-farm economic rate of nitrogen to apply. Substantial changes in the value of the crop produce or in the cost of nitrogen are needed to alter the recommendations. Where appropriate, different recommendations are given to achieve crop quality specifications required for different markets.

Application of nitrogen above the on-farm economic optimum will increase yield slightly, but this yield increase will be worth less than the cost of the extra nitrogen.

Maximum yield (C) is reached at a nitrogen rate greater than the on-farm economic optimum and is never a target if farm profits are to be maximised. Application of nitrogen above point C does not increase yield, and yield falls with further applications.

The nitrogen can be supplied from fertiliser and/or organic materials.

Nitrogen supply

Nitrogen supply can be from the soil, the atmosphere and organic manures, as well as from fertiliser.

Soil mineral nitrogen (SMN): Nitrate-N (NO_3-N) and ammonium-N (NH_4-N) are often called mineral nitrogen. Both are potentially available for crop uptake and the amount in the soil depends on the recent history of cropping, organic material and nitrogen fertiliser use.

Nitrogen mineralised from organic matter: Mineralisation results in the conversion of organic nitrogen to mineral nitrogen by soil microbes. The amount of organic nitrogen mineralised can be large:

- On organic and peaty soils
- Where organic manures have been used for many years
- Where nitrogen-rich, organic material is ploughed into the soil

Nitrogen from the atmosphere: Small amounts of nitrogen are deposited in rainfall and directly from the atmosphere. Leguminous crops, like peas, beans and clover, have bacteria in the nodules on the roots that can ‘fix’ atmospheric nitrogen into a form that can be used by the plant.

Nitrogen from organic materials: Most organic materials contain some mineral nitrogen, which is equivalent to mineral nitrogen in manufactured fertilisers. The remaining organic nitrogen becomes available more slowly (see **Section 2: Organic materials**).

Manufactured fertiliser nitrogen: Manufactured fertiliser nitrogen is used to make up any shortfall in the crop’s requirement for nitrogen.

Nitrogen losses

Nitrogen losses may occur by leaching, run-off, ammonia volatilisation and denitrification.

Leaching: Nitrate is soluble in the soil solution and, unlike ammonium, is not held on soil particles. Once the soil is fully wetted, nitrate may leach into field drains or subsurface aquifers as drainage water moves through the soil. The amount of winter rainfall has an important influence on the amount of nitrate leached.

Under normal conditions, ammonium-N in the soil is rapidly converted to nitrate. Therefore, sources of ammonium-N will have a similar risk of leaching as sources containing nitrate when used in excess of the requirement of a crop.

Run-off: During and following heavy rainfall, nitrogen in solution or in organic form can move across the soil surface and/or via drains and enter watercourses. The amount of nitrogen lost from soil in this way will vary widely from field to field and season to season depending on the amount, timing and intensity of rainfall and nitrogen applications. Sloping ground, proximity to surface waters and surface application of organic manures present particular risks of nitrogen loss in run-off.

Denitrification: In anaerobic soils (poorly aerated soils lacking oxygen), nitrate can be denitrified and lost to the atmosphere as the gases nitrous oxide (a greenhouse gas) and nitrogen (N_2). Denitrification is a biological process and is most significant in wet and warm soils where there is a supply of nitrate after harvest, or where there has been a recent nitrogen application and there is enough organic matter for the microbes to feed on. Some nitrous oxide is formed during nitrification of ammonium-N to nitrate-N and some of this also can be lost to the atmosphere.

Ammonia volatilisation: Nitrogen may be lost to the atmosphere as ammonia gas. Significant losses commonly occur from livestock housing, livestock grazing and where organic manures are applied to fields and are not immediately incorporated by cultivation. There can also be significantly larger losses of ammonia when urea is applied to a growing crop compared with losses when other forms of nitrogen fertiliser, such as ammonium nitrate, or inhibitor-treated urea, are used.

Factors influencing decisions about nitrogen use

The crop nitrogen requirement (the on-farm economic optimum) will depend on:

- The amount of nitrogen from all sources, including the soil and organic materials, which is available to achieve the optimum on-farm economic yield
- The cost of nitrogen fertiliser and the likely value of the crop
- Any particular crop quality requirements, for example, grain protein in bread-making wheat or in malting barley

In addition to identifying crop nitrogen requirement as accurately as possible, it may be necessary to comply with regulatory restrictions on the amount or timing of applications, for instance, in Nitrate Vulnerable Zones (NVZs).

When calculating how much manufactured fertiliser nitrogen to use, all supplies and losses of nitrogen and the efficiency of fertiliser nitrogen use by the crop must be considered.

Soil nitrogen may be immobilised by the addition of organic materials with a high carbon:nitrogen ratio. This may result in a short-term increase in nitrogen requirement. More information on such organic materials (e.g. paper crumble) is provided in **Section 2: Organic materials**. Data are not available on additional nitrogen requirements related to straw or high carbon:nitrogen ratio compost.

Assessing the soil nitrogen supply (SNS)

Soil nitrogen supply is defined as the amount of nitrogen (kg N/ha) available for uptake from the soil by the crop throughout its entire life. It takes account of nitrogen losses but excludes nitrogen applied to the crop in manufactured fertilisers or manures.

The SNS includes three separate components:

SNS = Soil mineral nitrogen (SMN) + Estimate of nitrogen already in the crop + Estimate of mineralisable soil nitrogen

Where:

- Soil mineral nitrogen (kg N/ha) is the nitrate-N plus ammonium-N content of the soil within the normal maximum rooting depth of the crop
- Nitrogen already in the crop (kg N/ha) is the total content of nitrogen in the crop when the soil is sampled for SMN
- Mineralisable soil nitrogen (kg N/ha) is the estimated amount of nitrogen which becomes available for crop uptake from mineralisation of soil organic matter and crop debris during the growing season after sampling for SMN

The SNS depends on a range of factors, which commonly vary from field to field and from season to season. It is, therefore, important to assess the SNS for each field each year. The key factors influencing SNS are:

- Nitrogen residues left in the soil from fertiliser applied for the previous crop
- Nitrogen residues from any organic manure applied for the previous crop and in previous seasons
- Soil type and soil organic matter content
- Losses of nitrogen by leaching and other processes (the amount of winter rainfall is important)
- Nitrogen made available for crop uptake from mineralisation of soil organic matter and crop debris during the growing season

Mineral residues after harvest

The management and performance of a crop can have a significant effect on the amount of residual mineral nitrogen (nitrate-N and ammonium-N) in the soil at harvest. Residues are likely to be small if the amount of nitrogen applied matched, or was less than, crop requirement. The residues may be larger than average when yields are unusually small due to disease or drought.

Residues following cereals are generally lower than those following break crops. In ley–arable rotations, the nitrogen released from grass leys may persist for up to three years following ploughing, but the most useful nitrogen becomes available within the first one or two seasons.

Winter cover crops

Well-established cover crops, such as mustard, forage rape or phacelia, sown after harvest can take up significant amounts of soil mineral nitrogen and reduce the risk of nitrate leaching over winter. Generally, the earlier the cover crop can be established, the more mineral nitrogen will be taken up. However, there is limited evidence on the use of starter nitrogen fertiliser on cover crops for better establishment; evidence to date does not show consistent benefits from its use.

Early destruction of a well-established cover crop by the end of February can release useful quantities of nitrogen for the following spring crop; sufficient to increase the SNS Index. In the majority of cases, the SNS Index can be increased by one, and on occasion by two Indices.

When cover crops are destroyed in March or later, the amount and timing of nitrogen release is difficult to predict. Nitrogen mineralisation can be delayed by a high carbon:nitrogen ratio. The timing and duration of nutrient uptake in the following crop is also a factor, such that short-season crops may not have time to benefit from any mineralised nitrogen from a previous cover crop. If there is reason to believe nitrogen residues are likely to be smaller than usual, the Index may need to be adjusted downwards.

Recent research has shown that in most cases, the majority of the nitrogen is released into the soil within two months of destruction, although in some cases release can take longer. There are not enough data yet to determine likely release timings for specific destruction methods.

Further information

Opportunities for cover crops in conventional arable rotations
ahdb.org.uk/cover-crops

Effect of excess winter rainfall

The amount of nitrate leached will depend on the quantity in the soil when the soil reaches field capacity and through-drainage starts, the soil type and the amount of water draining through the soil (excess winter rainfall).

The excess winter rainfall is the rainfall between the time when the soil profile becomes fully wetted in the autumn (field capacity) and the end of drainage in the spring, minus evapotranspiration during this period (i.e. water lost through the growing crop).

Excess winter rainfall (mm) = **Rainfall between the time a soil reaches field capacity and the end of drainage** – **Evapotranspiration**

Light sand soils and some shallow soils can be described as ‘leaky’. Nitrate in these soils following harvest is fully leached in an average winter, even where substantial residues are present in the autumn. The SNS Index is nearly always 0 or 1 and is independent of previous cropping, except in low rainfall areas or after dry winters.

Deep clay and silt soils can be described as ‘retentive’. The leaching process is much slower and more of the nitrate residues in autumn will be available for crop uptake in the following spring. Differences in excess winter rainfall will have a large effect on SNS in these soils. Low levels of SNS (Index 0 and 1) are less frequent than on sandy soils. Other mineral soil types are intermediate between these two extremes.

Because of both regional and seasonal differences, separate SNS Index tables are given in **Sections 3–6** for low, moderate or high rainfall situations.

Further information

AHDB provides excess winter rainfall (EWR) data for the current season
ahdb.org.uk/ewr

Nitrogen released from mineralisation of organic matter

Nitrogen is released in mineral forms when microbial action breaks down soil organic matter. The rate of mineralisation depends on temperature and is usually slow over winter until soil temperature reaches around 4°C. In organic and peaty soils, mineralisation of soil organic matter in late spring and summer results in large quantities of nitrate becoming available for crop uptake.

Soil temperature often remains higher than 4°C for some weeks after harvest, supporting mineralisation in autumn that can contribute to the nitrogen requirement of an autumn-sown crop or to the risk and extent of nitrate leaching where the land remains uncropped.

Long-season crops (e.g. sugar beet) will utilise more mineralised nitrogen than crops which are harvested in mid- or late summer. For example, cereals make little use of nitrogen mineralised after June.

For the purposes of this guide, organic soils are considered to contain between 10% and 20% organic matter. The recommendations in the tables for organic soils are based on an organic matter content of 15%.

Peaty soils contain over 20% organic matter. They are always at SNS Index 5 or 6, irrespective of previous cropping, manuring history or excess winter rainfall. This is because the large amounts of organic nitrogen mineralised will usually be much greater than variations in the nitrogen residues due to previous cropping.

The amount of nitrogen mineralised from past applications of organic manures (over one year old) is difficult to estimate. The amount will generally be small. It can be greater where there has been a history of large, regular applications of organic manures and in these situations it can be worthwhile to sample the soil and analyse it for soil mineral nitrogen (SMN).

Organic nitrogen in crop debris from autumn-harvested crops usually mineralises quickly and nitrate is liable to loss by leaching over winter in the same way as mineral nitrate residues from fertilisers. Mineralisation of nitrogen-rich leafy debris is quicker than that of nitrogen-poor straw debris.

Organic nitrogen that is not mineralised quickly becomes available over a long time and may contribute little to the nitrogen supply of the following crop.

Examples of cropping situations where mineralised nitrogen from crop residues can make a useful contribution are:

- Incorporation of sugar beet tops, especially before a late-autumn-sown crop
- Where a second cauliflower crop is grown in the same season. Large amounts of leafy, nitrogen-rich crop debris will be returned to the soil after harvest of the first crop and will quickly release nitrate available for the next crop

Soil nitrogen supply (SNS) Index system

The nitrogen recommendations in this guide are based on seven SNS Indices and each Index is related to a quantity of SNS in kg N/ha. The SNS Index can be determined using field-specific information (the Field Assessment Method) without sampling and analysis for SMN. It can also be deduced using the results of soil sampling and analysis for SMN and an assessment of any nitrogen already taken up by the crop (the Measurement Method).

A nitrogen recommendation is obtained by determining the SNS Index of the field using one of these methods, then referring to the appropriate crop table to obtain the nitrogen recommendation for the selected Index.

The SNS Index system used for arable crops, such as cereals and oilseeds (**Section 4: Arable crops**), is not applicable for established grassland, field vegetables or established fruit crops.

Full details of the SNS Index system and how to use it (with examples) are given in **Sections 3–6**.

Field Assessment Method

In most situations, the SNS Index will be identified using the Field Assessment Method, which is based on field-specific information for previous cropping, previous fertiliser and manure use, soil type and winter rainfall. The SNS Index is read from tables and there is no requirement for soil sampling or analysis.

This method usually provides a satisfactory assessment of the SNS in typical arable rotations, but the Measurement Method may give a better result where the SNS is uncertain or could be above 120 kg N/ha.

Measurement Method

SNS is related to the cumulative effects of farming practice over several years and can be difficult to predict in some circumstances.

The Measurement Method should be targeted to fields where the supply of plant-available nitrogen in the soil could be unusually large (for example, above 120 kg N/ha in arable rotations), particularly where organic manures have been used regularly in recent years.

The crop nitrogen content of cereals and oilseed rape at the time of SMN sampling can be estimated using the scheme given in **Section 4: Arable crops**. No similar scheme is available for estimating the nitrogen content of other crops at this time of year.

It is much more difficult to obtain a reliable estimate of the nitrogen that will be made available from mineralisation of organic matter. On many mineral soils with 4% or less soil organic matter, this will be relatively small and no further adjustment is needed. On organic and peaty soils, or where a large amount of organic material (crop residues or organic manure) has been applied in recent years, large quantities of nitrogen can be mineralised.

Nitrogen uptake efficiency by crops

The efficiency of uptake of nitrogen from different sources varies, even for well-grown crops. Provided that the total SNS does not exceed demand, where the amount of SMN present within normal rooting depth is in the range 50–100 kg N/ha, on average, crops will take up an amount of soil nitrogen that is roughly equivalent, i.e. SMN is used with apparently 100% efficiency.

The efficiency with which SMN is recovered is likely to be less than 100% (and might typically be closer to 60%). This should be compensated for by additional soil nitrogen that becomes available for uptake during the growing season, mainly through mineralisation of crop residues and soil organic matter. However, for individual situations, actual efficiency of SMN use and the supply of mineralised N are likely to vary.

SNS estimates of less than 50 kg N/ha should be treated as 50 and no less. Unless high SNS results (>160 kg N/ha) are confidently expected due to the regular addition of organic manures or crop residues, they should be treated with caution.

The efficiency with which SMN is recovered is likely to be lower where a large amount is present, especially in the autumn below topsoil depth, on sandy soils or in high rainfall situations where nitrate leaching losses will be greater. Early establishment of crops may help to reduce losses and increase the uptake of SMN.

The application of amounts of nitrogen in line with crop requirement does not appear to decrease the uptake of soil nitrogen. However, the efficiency of uptake of both fertiliser and soil-derived nitrogen is often reduced for crops suffering from the adverse effects of disease, poor soil conditions, drought or other growth-inhibiting problems.

Research has shown that the uptake efficiency of fertiliser nitrogen by winter wheat and winter barley varies depending on the soil type. The values shown in Table 1.3 are largely based on work with ammonium nitrate and values for other types of nitrogen fertiliser may be different in some circumstances.

For example, on light sand soils, 70 kg N/ha is taken up by the crop for every 100 kg N/ha applied as fertiliser.

The winter wheat and winter barley recommendations in this guide are adjusted to take account of these differences in nitrogen fertiliser uptake efficiency due to soil type.

Table 1.3 Uptake efficiency of fertiliser nitrogen depending on the soil category

Soil category	Uptake efficiency (%)
Light sand soils	70
Medium, clay, silty, organic and peaty soils	60
Shallow soils over chalk and limestone	55

Timing of nitrogen applications

Correct timing of nitrogen fertiliser application is important so that crops make the best use of the nitrogen applied and there is minimum risk of losses and adverse environmental impact. As a general principle, nitrogen should be applied at the start of periods of rapid crop growth and nitrogen uptake.

The timing of nitrogen application can also have a range of other important effects on crop growth and quality.

- Too much seedbed nitrogen can reduce the establishment of small-seeded crops
- Early spring nitrogen will increase tillering of cereals. This may be beneficial, but too much nitrogen at this stage can increase the risk of lodging and reduce the potential bushel weight
- Late-applied nitrogen will increase the grain nitrogen/protein concentration of cereals

Recommended nitrogen timings for individual crops are given in the recommendation tables. However, NVZ rules relating to closed periods take priority and may also influence the timing of nitrogen applications.

Figure 1.4 (page 20) shows the typical pattern of nitrogen uptake by a winter wheat crop. It is easy to see why there is no benefit from applying autumn nitrogen to winter cereal crops. The nitrogen requirement is small during the autumn and winter and the supply from soil reserves is adequate to meet the requirement.

However, autumn nitrogen is recommended for establishment of some winter oilseed rape crops, due to a larger nitrogen requirement.

Figure 1.4 shows:

- In autumn/winter (A), there is only a small crop nitrogen requirement that can easily be met by soil nitrogen reserves. There is no need to apply nitrogen in autumn
- The main period of nitrogen uptake (B) is March–June, and during this growth period there is usually insufficient soil nitrogen to support unrestricted growth. Nitrogen fertiliser should be applied at the start of, and during, this period of growth

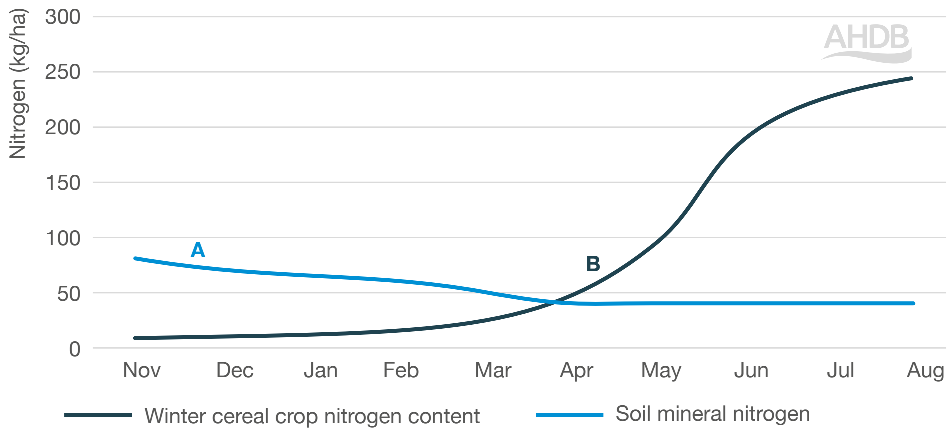

Figure 1.4 Nitrogen uptake by a winter cereal crop in relation to available soil nitrogen

The effect of economic changes

As a general principle, the recommendations are insensitive to changes in the value of the crop produce or the cost of nitrogen fertiliser. It would normally require a large change in the ratio of the value of a crop and the cost of nitrogen fertiliser to alter the recommendation.

The break-even ratio is the crop yield (kg) needed to pay for 1 kg of nitrogen. If there are large changes in the ratio (the break-even ratio), it will be appropriate to make adjustments in the recommendations.

$$\text{Break-even ratio} = \frac{\text{Cost of nitrogen (pence/kg)}}{\text{Value of crop produce (pence/kg)}}$$

The prices can be expressed in £/kg as long as both are in the same units (p/kg or £/kg). The nitrogen recommendation tables for wheat, barley, oats and oilseed rape (**Section 4: Arable crops**) show how to calculate adjustments to take account of the cost of nitrogen and the selling price of the grain produced.

Example 1.3

Ammonium nitrate (34.5% N) costs £230/t or $\frac{230 \times 100}{34.5 \times 10}$ = 67p/kg N

Wheat is sold for £110/t or $\frac{110 \times 100}{1{,}000}$ = 11 pence/kg

The break-even ratio is 67 ÷ 11 = 6

Further information

Tried & Tested
triedandtested.org.uk

AHDB GB fertiliser price series
ahdb.org.uk/GB-fertiliser-prices

Alternative approaches to nitrogen decisions

There is ongoing research into new approaches and techniques for deciding on nitrogen fertiliser use. The use of spectral reflectance sensors is one example that is increasingly being used to assess nitrogen requirement in the field. Other fertiliser nitrogen recommendation systems are based on models of crop growth and nitrogen uptake or on soil sampling to shallower depths than 90 cm. Some include a measurement of mineralisable nitrogen in a soil sample.

Provided a recommendation system takes proper account of the total amount of nitrogen needed by a crop and of the supplies available from the soil and organic manures, it should give a recommendation close to crop nitrogen requirement.

Phosphate, potash and magnesium for field crops

Phosphate, potash and magnesium applied in fertilisers and manures move slowly through the soil unless carried down through cracks or by earthworm activity. Many soils can hold large quantities of these nutrients in forms that are potentially available for crop uptake, after release from fixed forms. Crop-available levels are much smaller than potentially available levels.

Consequently, managing the supply of these nutrients for optimum yield is based on maintaining appropriate amounts in the soil for the needs of the rotation, rather than on those of an individual crop. In practice, this means maintaining target Soil Indices that ensure optimal phosphate, potash and magnesium nutrition.

As the amount of crop-available phosphate or potash in the soil increases from a very low level, crop yield increases, rapidly at first, then more slowly until it reaches a maximum. Typically, maximum yield of arable crops or grass is reached at Index 2 for phosphorus and Index 2- for potassium.

The principle for phosphate and potash management is to maintain the soil at the appropriate target Index. If the Index is lower than the target, yield may be reduced and additional phosphate and potash should be applied. If the Index is higher than the target, savings can be made by reducing or omitting applications until the soil level falls to the target Index.

Effective use of target Indices depends on representative soil sampling. If it is felt that significant areas of the field could differ in P or K Index; these areas should be sampled and treated separately.

Soils can be maintained at the current Index by replacing the amount of each nutrient removed from the field in the harvested crop. These amounts can be calculated from the actual or estimated yield (including straw if removed) and the concentration of the nutrient in the harvested product(s) as analysed or assumed (see **Sections 3–6**).

To check that this approach is maintaining the required P or K Index (i.e. the phosphate and potash status of the soil), soil sampling should be carried out every 3–5 years, at a suitable time in the crop rotation. Maintaining the appropriate level of phosphate and potash in the soil is especially important, as once a deficiency has occurred, a fresh application of phosphate and potash is unlikely to be available for uptake by roots in time to benefit the crop being grown.

Managing soil phosphate, potash and magnesium supply

An appropriate approach for managing phosphate, potash and magnesium to maintain soil fertility must take account of:

- Current Soil Index in the field
- Target Index or critical level of each nutrient for the rotation
- Need to build up, maintain or run down the Soil Index
- Responsiveness of all crops in the intended rotation to a fresh application of each nutrient
- Quantity of each nutrient removed from the field in crop produce
- The quantity of each nutrient applied in any organic materials (**Section 2: Organic materials**)

Recommendations for phosphate, potash and magnesium applications to build up soils and maintenance applications are given in **Sections 3–7**. The recommendations are given as kg/ha of P_2O_5, K_2O and MgO. This is because the concentrations of phosphorus, potassium and magnesium are expressed in this way in fertilisers and this makes it easier to calculate the amount of fertiliser to apply.

Soil sampling and analysis

Good management of pH, soil phosphate, potash and magnesium depends on soil sampling and analysis. Levels of these nutrients in the soil change only slowly, so soil sampling and analysis can be done every 3–5 years at an appropriate time in the crop rotation. It is usually safe to use soil analysis results for phosphorus, potassium and magnesium as a basis for fertiliser recommendations for up to four years from the date of sampling.

In variable fields, GPS sampling of soils for pH, P, K and Mg, combined with variable-rate nutrient and lime applications, can be cost-effective. Identifying significant changes in soil type or yield variation in the field is a key step in establishing the need for GPS sampling.

The analytical results will only be meaningful if an adequate, representative soil sample is taken. The recommended procedure for sampling soils is described in **Sections 3–7**.

It is best to use the same laboratory for all successive batches of samples and interpret the results together. Compare results with previous results from the same land. Investigate any odd or inconsistent analyses. Repeat (sample and analyse) any inexplicable results.

Collate soil nutrient results with estimates of nutrient removals. Note whether soil nutrient changes are large or small and whether they are explained by nutrient balances (additions minus removals). If available, use an appropriate spreadsheet, or proprietary software, to integrate soil analyses and crop removal data and deduce necessary nutrient balances for maintenance, and nutrient amounts needed to build up or run down soil levels.

Sampling of the subsoil (30–60 cm) can give useful information on soil nutrient supply and on lime requirement. Deep-rooting crops like cereals and sugar beet exploit the subsoil, which can differ from topsoil in nutrient concentrations and in pH. These crops can obtain 30% or more of their potassium supply from the subsoil. Ploughing under manure or potash fertiliser could be considered where subsoil testing reveals low potassium (Index 0 or low 1).

For advisory purposes, the soil nutrient results are usually given as milligrams of phosphorus, potassium and magnesium per litre of soil (mg P/litre, mg K/litre, and mg Mg/litre). The results are also given as an Index and the Indices range from 0 to 9. The Index system is based on the likely response of a crop to a fresh application of the nutrient. Index 0 soils are deficient and there would be an increase in yield by applying phosphate or potash. As the Index number increases, the response to a fresh application of fertiliser declines and for most soils growing arable crops, there would be no, or only a very small, response at Index 2.

The fertiliser recommendations given in this guide are based on the results of soil analysis using the following standard laboratory methods (Table 1.4). These methods, which are well-tried and tested over many years, are appropriate for soils in England and Wales.

Table 1.4 Method of extraction for phosphorus, potassium and magnesium

Nutrient	Method of extraction
Phosphorus (P)	Measured in a sodium bicarbonate soil extract at pH 8.5 (Olsen P)
Potassium (K) and magnesium (Mg)	Measured in an ammonium nitrate soil extract (exchangeable K and exchangeable Mg)

Crop analysis

Crop analysis can target leaves, to indicate whether the P or K concentrations in crops are at, or below, optimum levels at a particular point in time. Analyses of grains, tubers and other harvested materials can also be used to check the final crop nutrient status and nutrient offtakes.

Crop analysis should not be a substitute for a good soil-testing programme and it will be more effective when used in conjunction with soil testing.

To provide meaningful information, testing should be carried out at a defined growth stage and on a specific part of the plant, for which standard thresholds are known. For example, for winter wheat, testing is best carried out on the newest fully expanded leaf blade during stem extension (between GS31 and GS39). At such times, diagnostic sampling in good and bad parts of a crop can be a useful method to determine whether there is a nutrient deficiency.

Laboratories typically analyse plant tissue for nutrients by measuring their concentrations in the dry matter. Critical or threshold concentrations are known for some nutrients in some crop species (see **Sections 3–7**). Threshold levels tend to decrease as the crop grows. A threshold level of 0.32% P in wheat grain has been shown in recent research. P and K concentrations can also be measured in the leaf tissue water (cell sap) on farm using appropriate equipment, but these are prone to short-term fluctuations and may be less useful.

Potash-releasing clay soils

Depending on the nature of the minerals in the parent material from which they were developed, some heavy clay soils contain large quantities of potash. Weathering (breakdown) of these minerals releases the potash, which gradually becomes available for crop uptake.

Unfortunately, no routine soil analysis method is available to estimate the amount or rate of release of this potash. However, the potash that is released goes to the readily crop-available pool measured by soil analysis so that this value does not decline as quickly if the amount of potash applied is less than that removed in the harvested crops.

Local knowledge and past experience can be useful when assessing the potash-release characteristics of clay soils. If the crop-available potash status of a clay soil changes little when the potash balance is consistently negative over a number of years, this is a useful indicator that potash is being released from the clay by weathering.

A guide to classification of clays is given in Table 1.5. High-potash-releasing clays release up to 50 kg K_2O/ha in crop-available form each year without any reduction in K Index; intermediate clays release smaller but significant amounts.

On such soils, if potash historically has not been applied, it is essential to monitor crop yields to ensure that the yield potential of the site is being reached; if this is not the case, then potash fertilisers ought to be applied. Some potash application is likely to be needed when there are large removals in baled cereals, forage or energy crops. Regular soil testing remains necessary because where the soil K level is allowed to fall below the target Index, the quantity of potash required (over and above offtake) to raise the level in the soil can be greater for potash-releasing clays than it is for other clay soils.

Table 1.5 Classification of clays

High-potash-releasing clays*	Intermediate	Non-releasing clays
Chalky boulder clay	Decalcified boulder clay	Clay-with-flints
Gault clay	Clayey over limestone, lower chalk or marl	Carboniferous clay
Kimmeridge clay	London clay	Northern till
Oxford clay	Weald clay	
Charmouth (Lias) clay	Triassic (red) clays	

*Where topsoil is medium textured or has stones (apart from chalky boulder clay), move to Intermediate category.

Target Soil Indices

Crop-available nutrients are estimated by the laboratory methods given in Table 1.4 (page 22). Critical values for all three nutrients are represented by target Indices. Fertiliser and organic material applications should aim to raise the Index to the appropriate target for the rotation (Table 1.6) and then to maintain this target by maintenance applications.

The amount of applied P required (over and above offtake) to raise soil P levels will vary according to soil type and farming system; to determine these amounts see the detailed guidance on soil sampling and analysis in **Sections 3–7**.

Table 1.6 Target Soil Indices for soil P and K

	Soil P (mg/litre)	Soil K (mg/litre)
Arable, grassland and forage crops[ac]	Index 2 (16–25)[a]	Index 2- (121–180)
Vegetables[bc]	Index 3 (26–45)[b]	Index 2+ (181–240)

a. In rotations where most crops are autumn-sown, soils are in good condition (use VESS score below) and P is applied annually, high Index 1 can be an adequate target.

b. If vegetables (for example potatoes) are only grown occasionally as part of an arable rotation, it will be most economic to target Index 2 as for arable and forage crops.

c. Try to maintain the midpoint in these target indices to allow for variation across the area sampled.

On calcareous soils (with free calcium carbonate), it may not be possible to maintain Olsen P at the target Index due to the rapid P reversion processes. In these situations, it may be more appropriate to maintain soils at P Index 1 and apply fresh P fertiliser on an annual basis to achieve the yields expected at P Index 2.

Where crops are grown on soils below the target P Index, it may be possible to raise yields to the level achieved at the target Index by applying phosphate fertiliser at higher than recommended rates. However, this is generally not possible at P Index 0.

Efficient use of P and K is most likely to be achieved on soils that are well structured and enable good rooting. For visual evaluation of soil structure (VESS), a score of 1 or 2 would be considered adequate.

Further information

For further information on structural assessment of soils, the following resources could be used:

thinksoils
ahdb.org.uk/thinksoils

How to assess soil structure
ahdb.org.uk/vess

Maintaining the Soil Index

The amount of phosphate and potash required for maintenance, in kg P_2O_5/ha and kg K_2O/ha, can be calculated from the yield of the crop that is to be removed from the field and its nutrient content. Typical values for the content of phosphate and potash in crops are given in **Sections 3–7**, or contents can be determined by direct analysis.

For cereals, offtake in grain plus straw (where removed) can be determined from an estimate of grain yield alone. Where that applies, recommendations in this guide assume that, on average, removed straw weight is 50% of grain yield. However, straw removals can vary substantially and may be best estimated on an individual basis.

The phosphate and potash recommendations in this guide for arable crops grown on Index 2 soils are based on typical yields as indicated in the individual crop recommendations (for example, 8 t/ha for winter wheat). For cereals and oilseeds, where targeted yield is significantly greater or less than typical, the amounts of phosphate and potash likely to be removed by the crop should be calculated as shown in Example 1.4 (page 25). This amount should be used as the maintenance application at the target Index.

For potatoes, only potash should be adjusted in this way. The amount of phosphate removed by potatoes is usually much less than the amount applied. The residue from this surplus application should be taken into account for the following crop.

Replacing the phosphate and potash removed in the harvested crop may not maintain the appropriate Soil Index. Therefore, sample and analyse the soil at least every 3–5 years to check that the target Index is being maintained.

No replacement application is shown for magnesium for a number of reasons. The amounts of magnesium removed in a harvested crop tend to be small, perhaps 10–15 kg MgO/ha, and it appears that this amount of magnesium can be released during the weathering of clay minerals in many soils.

Consequently, the amount of exchangeable magnesium in soil tends to change slowly. Rather than an annual replacement, it is better to monitor change in exchangeable magnesium and apply fertiliser when the soil declines to Mg Index 1, especially to sensitive crops like sugar beet and some vegetable crops.

Building up or running down Soil Indices

To raise the level of a soil at Index 0 and 1 to Index 2 requires the application of more fertiliser than that needed for the maintenance dressing. The amount of extra fertiliser needed each time is determined by the number of years over which the Index is to be raised (Table 1.7). Raising Indices over a shorter period of time minimises the period of yield loss, but in the short term will increase the annual cost and risk of water pollution.

Large amounts of phosphate and potash may be required to raise the crop-available phosphate and potash in the soil by one Index and it is difficult to give accurate amounts.

For example, to increase soil Olsen P by 10 mg/l may require approximately 200–300 kg/ha P_2O_5 (i.e. 435–650 kg/ha of triple superphosphate). Similarly, to increase soil potash by 50 mg K/l, 300–500 kg K_2O/ha as a potash fertiliser (i.e. 500–800 kg/ha of muriate of potash) may be required.

The amount to apply at each dressing is a business decision that depends on how quickly the land manager aims to increase the asset value of the land. Consequently, two sets of build-up application rates are shown in Table 1.7 with the approximate time over which Index 2 can be reached. These amounts have been calculated using the midpoint values for each initial Index (as mg/l), compared with the midpoint value of the target Index.

Table 1.7 Adjusting applications for Soil Index

Current P or K Index	Adjustment to application (kg/ha)	
	10–15 year-period to adjust Soil Index	5–10 year-period to adjust Soil Index
0	+60	+100
1	+30	+50
2 or higher	No phosphate or potash required	

Further information

Potash Development Association PK calculator
pda.org.uk/calculator/pkcalculator

In some situations (e.g. phosphate for potatoes), the crop is likely to respond to larger amounts of nutrients than would be recommended using the above adjustments. The recommendations given in **Sections 3–7** are the higher of:

- The rate of nutrient required for maximum crop response
- The rate of nutrient based on the maintenance dressing plus the amount suggested in Table 1.7 (page 24) to increase the Soil Index in 10–15 years

Where a rapid increase in the Soil Index level is required, larger amounts of organic manures and fertilisers may be applied, but they should be ploughed in and well mixed with the soil by cultivation. In this situation, frequent soil analysis is recommended to ensure that the desired Index level is not exceeded.

Where the Soil Index is well above the target level, not applying fertiliser will allow for a gradual decline to the target level. For many arable crops and grassland, it could be appropriate not to apply any fertiliser unless the crop responds to a small amount placed near the seed.

If plant-available phosphate and potash are being run down, then it is essential to follow the decline by regular soil analysis to ensure that the level does not fall below the appropriate target Index.

Building up crop-available levels of phosphate and potash in soil or letting them decline is a decision for the farmer to make. However, the following should be considered:

- Experimental evidence shows that applying the maintenance dressing of phosphate and potash fertilisers to soils at Index 0, even with the suggested addition for build-up, will rarely increase the yield of many arable crops to that achieved on Index 2 soils given the maintenance dressing alone
- Land where soil P has recently been built up to the target Index will generally have less soil P reserves (immobilised but potentially available P) than land that has been maintained at, or run down to, the target Index over recent years. To avoid poor crop performance, P management of recently built-up land will require more care. For example, more frequent soil and crop analysis and more regular fertiliser or manure applications. Also, land recently built up to the target Index will run down more rapidly than land that has recently been maintained at, or run down to, the target Index
- Continuing to apply phosphate and potash as fertilisers or manures to soils above the target Index (except where vegetable crops are grown) is an unnecessary expense and an environmental risk

Example 1.4

The application of phosphate and potash to a winter wheat crop should be adjusted according to the Soil Index and expected yield. Regular soil analysis is essential to ensure the Index does not fall below the target.

Offtake						Application to replace offtake	
Grain yield (t/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)	Straw yield[a] (t/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)	P_2O_5 (kg/ha)[b]	K_2O (kg/ha)[b]
6	39	33	3	4	29	45	60
8	52	44	4	5	38	55	80
10	65	55	5	6	48	70	105
12	78	66	6	7	57	85	125

a. Standard recommendations assume straw yield will be 50% of grain yield.

b. To nearest 5 kg/ha.

Soil P Index and loss of phosphate from soil

Particular care should be taken to avoid building up crop-available phosphate above the target Index. Recent research has shown that phosphate transfer from soil to surface water increases as soil P Index increases. Much of this transfer is due to the loss of crop-available phosphate through land run-off.

To reduce the risk of phosphate transfer, every effort should be made to minimise the chance of soil erosion and prevent the unnecessary build-up of available soil phosphate. Phosphate transferred from soil to surface fresh-water bodies may cause algal blooms and other adverse effects on the biological balance in the water.

Potash use in sandy and sandy loam soils

Sandy and sandy loam soils, together with other soils containing very little clay, have a limited capacity to hold potash. On such soils, it is almost impossible to achieve the target soil K Indices of 2- (for arable, grass and forage crops) or 2+ (for vegetables).

For sandy loams, it is generally possible to maintain soil at 150 mg K/l (Index 2-), but for sands and loamy sands, the realistic upper limit is 100 mg K/l (upper Index 1). Adding potash fertilisers to try to exceed these values will result in the movement of potash into the subsoil, where it may only be available to deep-rooted crops.

On sands, it is preferable to apply and cultivate into the topsoil an amount of potash fertiliser each year to meet the potash requirements of the crop to be grown. Note that this may be higher than the expected offtake at harvest.

Responsive situations

Potatoes, some field vegetables and forage maize may respond to fresh applications of phosphate, even where the soil P Index is at, or slightly above, the target Index level for the rotation. For these crops, special methods of application, such as placement or band-spreading, may be advantageous.

For some crops, particularly small-seeded vegetables, starter applications of phosphate placed close to the seed may improve establishment, even on soils at P Index 3 and above. On soils at P Index 2 and above, the amount of phosphate applied as a starter dose, together with the amount added in the base dressing, should not exceed the amount of phosphate required to replace that removed by the previous crop.

Point to consider

There is a serious risk of damage to germinating seedlings if base fertiliser formulations containing potash salts are used as starter fertilisers. For further information, consult a FACTS Qualified Adviser.

Soil Mg Index

Analysis for magnesium is done on the same soil extract as that used to determine potassium. Very low soil magnesium (Index 0) is common on sandy/light loamy, stony or chalk soils. Low Mg (Index 1) is possible on medium soils, especially where alkaline, though these soils have additional reserves in the subsoil.

Potatoes, sugar beet and vegetable crops are susceptible to magnesium deficiency and show yield responses to magnesium fertiliser at Mg Index 0 or 1. In such cases, 50–100 kg/ha MgO should be applied before the responsive crop.

Oilseed rape and leguminous crops might respond to small applications of magnesium fertiliser at Index 1, though recent trial information is sparse. Cereals frequently exhibit deficiency symptoms early in the season when root growth is restricted, but these can disappear as roots grow. For light loamy, stony or chalky soils in rotations of combinable crops, maintenance of Mg Index 1 is a satisfactory policy and could be achieved by small annual applications (10–15 MgO kg/ha) or by slightly larger amounts targeted at oilseed rape or legumes in the rotation. Larger applications are justified at Index 0. Because magnesium is subject to leaching, fertilisation to maintain at Index 2 is unnecessary and uneconomic, although is achievable when fields are rotationally manured.

Where the Mg Index is low and soil acidity needs to be corrected, applying magnesian limestone may be cost-effective. An application of 5 t/ha of magnesian limestone will add at least 750 kg MgO/ha and this magnesium will become available to the crop over many years.

High magnesium is a natural property of many heavy soils which sustain Index 4 or 5 and soils formed on dolomitic limestones or mudstones often are Index 6. Where soil magnesium exceeds Index 5, there are some concerns about reduced potassium availability and about some risk of instability in soil structure. If such soils need lime, it is best to use a calcium lime source, which will reduce magnesium levels gradually.

Sulphur

Sulphur is a major plant nutrient. Plants need about the same amount of sulphur as phosphorus.

In the past, large amounts of sulphur were released into the atmosphere from industrial processes and this was deposited on land. However, atmospheric deposition has declined greatly in recent decades and the majority of crops grown in the UK can no longer be expected to obtain much of their sulphur requirements from sulphur deposition.

Sulphur is important because:

- Yield can be reduced when sulphur is deficient but visual symptoms are absent
- Nitrogen fertiliser may not be fully utilised if sulphur is deficient
- Correct sulphur fertilisation improves quality of grains and oilseeds
- Sulphur application is currently very cost-effective and is not associated with any major environmental problems

Point to consider

Although roots take up sulphur as sulphate (SO_4), recommended rates and the content of fertilisers and organic material are expressed as either SO_3 or sulphur.

Sulphur deficiency

There is an increasing risk of sulphur deficiency in the UK in a wide range of crops, including cereals, oilseed rape, brassica vegetables, peas and grass. Oilseed rape and grass grown for silage are particularly sensitive to sulphur deficiency.

Most soils, especially chalky or sandy soils, store very little sulphate from one year to the next. This is because sulphate is water-soluble and easily leached.

As atmospheric deposition of sulphur continues to decline, it is likely that the risk of deficiency will affect an increasingly wide range of crops grown on many different soil types.

The best guide for assessing the risk of sulphur deficiency is soil type and field location, although fields that have received regular applications of organic manure are less likely to show deficiency.

Sulphur is retained in soil organic matter and can become available to plants when organic matter is decomposed by soil microbes. On mineral soils, sulphur should be applied to all winter oilseed rape crops and to all cereal, grass, grain legume, brassica vegetable and sugar beet crops grown in high-risk sulphur-deficiency situations (Table 1.8, page 28).

Where sulphur deficiency has been diagnosed or is expected, it can be corrected by applying a manufactured sulphur fertiliser and/or livestock manure or biosolids (**Section 2: Organic materials**). As most soils store very little sulphur from one year to the next, applications of sulphur will be necessary year after year for the susceptible crop.

Sulphur in livestock manures and biosolids is available in two main forms:

- Readily available sulphur, which can be taken up immediately by the crop
- Organic sulphur, which is not immediately available for crop uptake but may be mineralised to readily available sulphur over subsequent months and years

Readily available sulphur + organic sulphur = total sulphur

When planning the use of nutrients, it is important to make allowance for those contained in organic materials. Use Table 2.1 (**Section 2: Organic materials**) to determine sulphur availability from different organic materials.

Diagnostic methods

Visual symptoms, such as paling of young leaves and crop stunting, can be used to diagnose moderate to severe cases of sulphur deficiency. However, these symptoms can be easily confused with other nutrient deficiencies or crop stress and, by the time they appear, it can be too late to correct the deficiency. It is likely to be difficult to identify the slight visual symptoms normally associated with minor sulphur deficiency that may still result in significant yield loss.

If a deficiency is suspected, tissue analysis in the spring can be a useful diagnostic tool, used in combination with the sulphur deficiency risk categories based on soil type and over-winter rainfall (Table 1.8 page 28).

The procedures for plant sampling and interpretation of analytical results are given with each crop recommendation table in their relevant section of the Nutrient Management Guide (RB209).

Table 1.8. Sulphur deficiency risk categories

Soil category	Winter rainfall (Nov–Feb)		
	Low (<175 mm)	Medium (175–375 mm)	High (>375 mm)
Light sand and shallow	High	High	High
Medium	Low	High	High
Deep clayey, deep silty, organic and peaty	Low	Low	High

Sodium

Sodium is recommended for certain crops (e.g. sugar beet and carrots). Soil analysis can be used to identify the need to apply sodium for sugar beet.

If a deficiency is suspected, ensure that an analysis package is chosen that includes sodium.

The interpretation of soil analysis results is given in the crop recommendation tables in their relevant sections of the Nutrient Management Guide (RB209). At recommended rates, sodium should have no adverse effect on the physical condition of soils.

In grassland systems, it is important to maintain an adequate amount of sodium in livestock diets. Sodium application will not have any effect on grass growth but has been reported to improve the palatability of grass.

Micronutrients (trace elements)

Micronutrients are those crop nutrients required in small amounts for essential growth processes in plants and animals. Some micronutrients that are essential for animals are not required by plants, but the animal usually acquires them via the plant.

In practice, only a few micronutrients are known to be present in such small amounts in soil that there is a risk of deficiency in plants and animals. Deficiency is most frequently related to soil type, soil pH, soil structural conditions and their effect on root growth and crop susceptibility.

For continuous arable cropping on mineral soils, the maximum availability of nutrients from the soil is achieved at pH 6.5. To maintain an appropriate pH, test soils every 3–5 years and treat acidic soils with a liming material.

Visual symptoms of a deficiency of a specific micronutrient are often short-lived and can be confused with those produced by other growth problems. Furthermore, by the time symptoms appear, it can be too late to correct a deficiency.

Consequently, decisions about when to apply micronutrients should be informed by crop and soil risk factors (**Sections 3–7**), and visual diagnosis of a micronutrient deficiency should, where appropriate, be confirmed by plant and/or soil analysis.

Soil analysis for micronutrient deficiencies may be done on the same samples taken every 3–5 years for routine analysis of P, K, Mg and pH.

If a deficiency is suspected, ensure that an analysis package is chosen that includes the micronutrients in question. In such cases, leaf analysis in the spring and/or crop analysis at harvest can be useful in reaching a diagnosis. If such analyses indicate a deficiency, it is important to investigate further.

The soil may contain adequate amounts of the nutrient and the deficiency may simply have been caused by reduced availability, due to adverse (e.g. dry) weather conditions, poor rooting or inappropriate soil pH. For these reasons, soil samples should be taken after harvest to confirm whether deficiencies are caused by soil supplies.

Deficiencies affecting crop growth

Boron (B): Deficiency can affect sugar beet, brassica crops and carrots on light-textured soils with a pH above 6.5, particularly in dry seasons. Symptoms include death of the apical growing point and growth of lateral buds. In sugar beet, there is blackening at the leaf base and beneath the crown ('heart-rot'). Carrots can show a darkening of the root surface ('shadow').

Soil analysis prior to growing a susceptible crop is recommended. When extracted with hot water, a value less than 0.8 mg B/l dry soil is associated with a risk of deficiency. Leaf analysis is also a useful diagnostic guide and a value lower than 20 mg B/kg dry matter may indicate deficiency (although the deficiency value varies between crop species).

Copper (Cu): Deficiency is not widespread in crops but can occur mainly in cereals on sands, peats, reclaimed heathland and shallow soils over chalk. Sugar beet may also be affected.

In cereals, symptoms are yellowing of the tip of the youngest leaf, followed by spiralling and distortion of the leaf. Ears can be trapped in the leaf sheath and those that emerge have white tips. Barley awns can become white. Soil analysis is useful for identifying whether deficiency is likely.

When extracted with EDTA, a value lower than 1 mg Cu/l dry soil indicates possible deficiency. The copper content of the leaf does not reliably indicate the copper status of the plant.

Iron (Fe): Deficiency occurs commonly in fruit crops grown on calcareous soils but is not a problem in annual field crops. Symptoms in fruit are yellowing of the young leaves with veins remaining green. Deficiency cannot be reliably diagnosed using soil or plant analysis.

Manganese (Mn): Manganese is the micronutrient most commonly deficient in field crops. Deficiency occurs in many crops on peaty, organic and sandy soils at high pH but can occur less severely on other soils when over-limed.

Susceptible crops include sugar beet, cereals and peas. In cereals, deficiency often shows as patches of pale green, limp foliage. Sugar beet leaves develop interveinal mottling and leaf margins curl inwards. Dried peas show internal discolouration when the pea is split ('marsh spot'). Leaf analysis provides a reliable means of diagnosis, with a value lower than 20 mg/kg dry matter indicating possible deficiency. Soil analysis is not a reliable guide to deficiency.

Molybdenum (Mo): Deficiency is associated with acidic soils and is not generally a problem in limed soils. Cauliflower may be affected and symptoms include restricted growth of the leaf lamina ('whiptail').

Soil or plant tissue analyses may be used to diagnose molybdenum deficiency. Soil analysis is usually by extraction with acid ammonium oxalate ('Tamm's reagent'). The leaf and curd content in dry material is around 2.0 mg Mo/kg in normal cauliflower plants and around 0.35 mg Mo/kg in deficient plants.

Zinc (Zn): Deficiency is rarely found in field crops. In the few cases where deficiency has been found, it has been on sandy soils, with a high pH and phosphate status. Top fruit and forest nursery stock are most likely to be affected.

Leaf analysis is the most useful diagnostic guide and, in susceptible crops, less than 15 mg Zn/kg dry matter may indicate deficiency. Soil analysis is usually by EDTA extraction. For susceptible crops, a value less than 0.5 mg Zn/kg indicates a risk of probable deficiency, while less than 1.50 mg Zn/kg indicates possible deficiency.

Deficiencies affecting livestock performance

The availability of cobalt, copper and selenium does not restrict grass growth, but too little in grazed crops can lead to deficiency in some animals. Where a deficiency has been correctly diagnosed, treatment of the animal with the appropriate trace element is usually the most effective means of control, though application of selenium and cobalt to grazing pastures can be effective.

Further information

Webinar: Trace elements in beef and sheep production
AHDB Beef & Lamb YouTube channel

Fertiliser types and quality

It is important to select the most appropriate and cost-effective material from the many different types of fertiliser that are available in both solid and fluid forms. The following features of a fertiliser should be considered:

- The total concentration and the ratio of nutrients in the fertiliser
- The chemical form of each nutrient
- The physical quality of a solid fertiliser and its suitability for accurate spreading
- The form of a liquid fertiliser, true solution or suspension
- The cost of the nutrients

The total concentration and the ratio of nutrients in the fertiliser

The total concentration of each nutrient in a fertiliser has to be declared. Straight fertilisers contain just one nutrient, whereas many fertilisers contain more than one. The requirements for nutrient declaration, including the chemical form of each nutrient and its availability for crop uptake, are controlled by national legislation originally transposed from European regulations. The nutrient content of some common fertilisers is given on page 34.

The concentration of nutrients in fluid fertilisers may be expressed as kg nutrient per tonne of fertiliser product (w/w basis) or as kg nutrient per cubic metre (1,000 litres) of fertiliser product (w/v basis). To convert from one basis to the other, it is necessary to know the specific gravity of the fertiliser. The fertiliser supplier can provide this information.

Concentration as w/v (kg/m^3) = concentration as w/w (kg/t) x specific gravity

The concentration of the nutrient or nutrients in a fertiliser dictates the application rate. When there is more than one nutrient, the ratio should be reasonably close to the required application of each nutrient.

Physical nature, quality and suitability of fertiliser

Fertilisers may be sold in many different physical forms, some of which may be difficult to apply accurately. Good fertiliser practice must include accurate, uniform application, as well as correct decisions on rate and timing.

Inaccurate application of fertiliser will result in uneven crops with lower-than-expected yields and the quality may be poor. Over-application may result in adverse environmental impact from pollution.

When spreading, it is important that the particle size of a solid fertiliser is consistent, free of lumps and low in dust, while the components of a fluid fertiliser should remain as a uniform solution or suspension.

The cost of the nutrients

The cost of the nutrients in fertilisers can vary significantly. When comparing fertiliser prices, it is necessary to calculate and compare the cost of each kg of nutrient. It is the cost per hectare, not the cost per tonne, which determines the economics of a fertiliser application.

Low-cost fertilisers can have a poor chemical or physical quality. The availability of the nutrients for crop uptake must be considered, as well as the accuracy of the fertiliser spreader or sprayer that is used.

Nitrogen fertilisers

Ammonium nitrate (33.5–34.5% N)/Ammonium sulphate (21% N, 60% SO_3)/Calcium ammonium nitrate (26–28% N): The nitrate-N is immediately available for crop uptake; the ammonium-N can be taken up directly but is quickly converted to nitrate by soil microbes.

Urea (46% N): Urea is quickly converted to plant-available ammonium-N by the enzyme urease which occurs in all soils.

Liquid nitrogen (18–30% N): Liquid nitrogen fertilisers are solutions of urea and ammonium nitrate. The nitrogen is in forms that are quickly available for crop uptake. Solutions based on urea alone will contain no more than 18% N because at low, ambient temperatures, urea crystallises out of solution.

The nitrogen content of applied urea lost to the atmosphere as ammonia varies depending on soil and weather conditions and is typically 10–30%. Losses may be minimised if urea is applied shortly before rain is expected and/or is shallowly cultivated into the soil.

Recommended nitrogen rates are based on the main nitrogen source being ammonium nitrate, ammonium sulphate or calcium ammonium nitrate. Urea can be treated with urease inhibitors to reduce losses through volatilisation.

If untreated urea is to be used, recommended rates may need to be adjusted to allow for losses as ammonia. It is unlikely that this adjustment will be necessary if urea is treated with a urease inhibitor. For complete agronomic advice on product choice and guidelines for use, consult a FACTS Qualified Adviser.

Nitrification inhibitors can slow the conversion of ammonium-N to nitrate-N. They can be added to liquid fertilisers prior to application or sprayed onto soil prior to spreading solid fertilisers. Nitrification inhibitors can delay the release of nitrate following fertiliser application, which can reduce nitrate leaching and nitrous oxide emissions.

Phosphate fertilisers

Water-soluble phosphate fertilisers are used very inefficiently, even by the first crop. For example, recovery (judged by its effect on uptake) from triple superphosphate is usually less than 10%. Until more efficient techniques or products become available, fresh fertiliser should only be relied upon to overcome small crop P deficiencies.

Lack of water solubility does not mean the phosphate is unavailable to crops. For example, finely ground, phosphate rocks with close to zero water solubility can be used successfully as a phosphate source on grassland where the surface soil pH is maintained below pH 6.0. Some other water-insoluble phosphates are an effective source of phosphate under appropriate soil and weather conditions; in these situations, seek advice from a FACTS Qualified Adviser about their use.

Water-soluble phosphate: Diammonium phosphate (DAP), monoammonium phosphate (MAP), triple superphosphate (TSP) and single superphosphate (SSP) contain phosphate that is mainly in a water-soluble form (93–95%).

Water-insoluble phosphate: There are many different types of water-insoluble phosphate with different chemical and physical characteristics. The fertiliser declaration should give details of the amount of phosphate soluble in different acid extractants. This information does not indicate the effectiveness of these sources of phosphate on different soil types. Care should be taken not to compare the solubility of water-insoluble phosphates in different reagents (for example, formic acid and citric acid) that extract different forms of phosphate.

Potash and magnesium fertilisers

Potash in most potash fertilisers is quickly available to crops. The most common potash source is muriate of potash (MOP), which is potassium chloride (60% K_2O). Kainit and sylvinite are naturally occurring mixtures of mainly potassium chloride and sodium chloride.

Potassium sulphate (SOP, 50% K_2O) is used for some high-value crops. Potassium nitrate supplies both potassium and nitrogen and is used as a source of both nutrients when added to irrigation systems.

Some magnesium fertilisers are quickly available (e.g. kieserite, typically 25% MgO; and Epsom salts, 16% MgO), though others are only slowly available (e.g. calcined magnesite and magnesian limestone).

Where both lime and magnesium are needed, magnesian limestone will often provide a cheap, though slow-acting, source of magnesium. An application of 5 t/ha of magnesian limestone will provide at least 750 kg MgO/ha and the magnesium becomes slowly available to crops over time.

Sulphur fertilisers

Ammonium sulphate (60% SO_3) and kieserite (typically 52–55% SO_3) provide sulphur in an immediately available form. Gypsum (calcium sulphate) is somewhat less soluble but is an effective source. Polyhalite is principally a sulphur fertiliser that contains 48% SO_3, 14% K_2O, 6% MgO and 17% CaO.

Elemental sulphur must be oxidised to sulphate before it becomes available for uptake. The speed of oxidation depends largely on particle size and only very finely divided (micronised) elemental sulphur will be rapidly effective. Where particle size is larger, elemental sulphur fertilisers can be used to raise the sulphur supply capacity of the soil over a longer period of time.

Further information

Fertiliser spreaders – choosing, maintaining and using
triedandtested.org.uk/media/bzif2w1q/fertiliser-spreader-manual.pdf

Fertiliser application

Accurate and even application of fertilisers is very important in order to maximise the benefits from their use to improve crop yield, quality and profitability. Even where correct decisions have been made on the amount of fertiliser to apply, inaccurate application, uneven spreading or spreading into hedgerows or ditches can cause a range of potentially serious problems, including:

- Reduced yields and/or quality caused by uneven crops (stripes), lodging and disease
- Higher risk of the transfer of nutrients to watercourses at field margins, causing nutrient pollution
- Higher risk of causing botanical changes in hedgerows and field margins

Spreading nitrogen fertilisers and organic materials as uniformly and accurately as is practically possible to the cropped area is a requirement in NVZs. Avoiding spreading into the edges of hedgerows and ditches is a requirement of cross compliance.

Fertiliser spreaders and sprayers should be regularly maintained and serviced, replacing worn-out parts as necessary. To do this, follow the manufacturer's instructions. Spreaders should be calibrated for rate of application every spring and whenever the fertiliser type is changed. To check spreading uniformity, catch-trays can be used. Ideally, this should be done annually or whenever faulty spreading is suspected.

Computerised analysis of the data will give the coefficient of variation (CV), which is a measure of the non-uniformity of spreading. Where the CV is larger than 15%, significant inaccuracies in fertiliser spreading are occurring. Action should then be taken to improve the performance of the spreader.

For manure and slurry spreaders, checks should be made for mechanical condition before spreading and for rate of application during spreading.

Other sources of useful information

ADAS
adas.co.uk

Agricultural Industries Confederation
agindustries.org.uk

Catchment Sensitive Farming (CSF)
gov.uk/guidance/catchment-sensitive-farming-reduce-agricultural-water-pollution

FACTS
basis-reg.co.uk

International Fertiliser Society
fertiliser-society.org

Potash Development Association (PDA)
pda.org.uk

SRUC
sruc.ac.uk

Nitrate Vulnerable Zones (NVZs)

Nitrate Vulnerable Zones (NVZs) – England
gov.uk/guidance/nutrient-management-nitrate-vulnerable-zones

Nitrate Vulnerable Zones (NVZs) – Scotland
gov.scot/policies/agriculture-and-the-environment/nvz/

farmingandwaterscotland.org/know-the-rules/

Nitrate Vulnerable Zones (NVZs) – Wales
gov.wales/water-resources-control-agricultural-pollution-wales-regulations-2021-guidance-farmers-and-land

Nitrate Vulnerable Zones (NVZs) – Northern Ireland
daera-ni.gov.uk/nutrientsactionprogramme2019-2022

Farming rules for water from April 2018

Guidance for farmers and land managers
gov.uk/guidance/rules-for-farmers-and-land-managers-to-prevent-water-pollution

Guidance for the Environment Agency
gov.uk/government/publications/applying-the-farming-rules-for-water/applying-the-farming-rules-for-water

Statutory Instruments

- The Ammonium Nitrate Materials (High Nitrogen Content) Safety Regulations 2003 (SI 1082)
- The EC Fertilisers (England and Wales) Regulations 2006 (SI 2486)
- The Fertilisers (Amendment) Regulations 1995, No 16
- The Fertilisers (Amendment) Regulations 1997, No 1543
- The Fertilisers (Amendment) Regulations 1998, No 2024
- The Fertilisers (Sampling and Analysis) Regulations 1996 (SI 1342)
- The Fertilisers Regulations 1991 (SI 2197)
- The Pollution Prevention and Control (England and Wales) Regulations 2000 (SI 800)
- The Sludge (Use in Agriculture) Regulations 1989 (SI 1263)
- The Sludge (Use in Agriculture) (Amendment) Regulations 1990 (SI 880)

legislation.gov.uk

Analysis of fertilisers and liming materials

The materials listed below are used individually and some are used as components of compound or multi-nutrient fertilisers. The chemical and physical forms of nutrient sources, as well as growing conditions, can influence the effectiveness of fertilisers. A FACTS Qualified Adviser can give advice on appropriate forms for different soil and crop conditions.

The reactivity, or fineness of grinding, of liming materials determines their speed of action. However, the amount of lime needed is determined mainly by its neutralising value.

Nitrogen fertilisers	Typical % nutrient content
Ammonium nitrate	33.5–34.5% N
Liquid nitrogen solutions	18–30% N (w/w)
Calcium ammonium nitrate (CAN)	26–28% N
Ammonium sulphate	21% N, 60% SO_3
Urea	46% N
Urea + urease inhibitor	46% N + NBPT
Urea + nitrification inhibitor	46% N + DCD
Calcium nitrate	15.5% N, 26% CaO

Phosphate fertilisers	Typical % nutrient content
Single superphosphate (SSP)	18–21% P_2O_5, typically 30% SO_3
Triple superphosphate (TSP)	45–46% P_2O_5
Diammonium phosphate (DAP)	18% N, 46% P_2O_5
Monoammonium phosphate (MAP)	12% N, 52% P_2O_5
Rock phosphate (e.g. Gafsa)	27–33% P_2O_5

Potash/magnesium/sodium fertilisers	Typical % nutrient content
Muriate of potash (MOP)	60% K_2O
Sulphate of potash (SOP)	50% K_2O, 45% SO_3
Potassium nitrate	13% N, 45% K_2O
Kainit	11% K_2O, 5% MgO, 26% Na_2O, 10% SO_3

Potash/magnesium/sodium fertilisers	Typical % nutrient content
Sylvinite	minimum 16% K_2O, typically 32% Na_2O
Kieserite (magnesium sulphate)	25% MgO, 50% SO_3
Calcined magnesite	typically 80% MgO
Epsom salts (magnesium sulphate)	16% MgO, 33% SO_3
Agricultural salt	50% Na_2O

Sulphur fertilisers	Typical % nutrient content
Ammonium sulphate	21% N, 60% SO_3
Epsom salts (magnesium sulphate)	16% MgO, 33% SO_3
Elemental sulphur	typically 200–225% SO_3 (80–90% S)
Quarried gypsum (calcium sulphate)	40% SO_3
Polyhalite (e.g. Polysulphate)	minimum 48% SO_3, 14% K_2O, 6% MgO, 17% CaO

Liming materials	Neutralising value (NV)
Ground chalk or limestone	50–55
Magnesian limestone	50–55, over 15% MgO
Hydrated lime	c.70
Burnt lime	c.80
Sugar beet lime	22–29 + typically 7–10 kg P_2O_5, 5–7 kg MgO, 4–6 kg SO_3/tonne

Glossary

Additionally available nitrogen (AAN)
Nitrogen that will become available to the crop through mineralisation during the growing season.

Anion
Negatively charged form of an atom or molecule, for example nitrate (NO_{3-}) and sulphate (SO_4^{2-}).

Available (nutrient)
Form of a nutrient that can be taken up by a crop immediately or within a short period so acting as an effective source of that nutrient for the crop.

Band-spreading
Application of fertiliser or slurry in bands along a row of seeds or crop plants.

Biosolids
Treated sewage sludge.

Calcareous soil
Soil that is alkaline due to the presence of free calcium carbonate or magnesium carbonate, or both.

Cation
Positively charged form of an atom or molecule, for example potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}) and ammonium (NH^{4+}).

Cation exchange capacity
Capacity of the soil to hold cations by electrostatic forces. Cations are held at exchange sites mainly on clay particles and organic matter.

Clay
Finely divided inorganic crystalline particles in soils, less than 0.002 mm in diameter.

Closed period
Period of the year when nitrogen fertilisers or certain manures should not be applied unless specifically permitted. Closed periods apply within NVZs.

Coefficient of variation (CV)
Measure of the unevenness of application of fertilisers or manures. CV of 0% indicates perfectly even spreading (unachievable in practice). Correct operation of a well-set-up spreader should give a CV of 10% for fertilisers and 25% for manures under field conditions.

Compost
Organic material produced by aerobic decomposition of biodegradable organic materials.

Content (nutrient)
Commonly used instead of the more accurate ‘concentration’ to describe nutrients in fertiliser or organic manure. For example, 6 kg N/t often is described as the nitrogen content of a manure.

Cover crop
A crop that provides potential benefits to a rotation. One primary benefit is taking up nitrogen from the soil after harvest to prevent nutrient losses via run-off and leaching. Also called green manure.

Crop-available nitrogen
The total nitrogen content of organic manure that is available for crop uptake in the growing season in which it is spread on land.

Crop nitrogen requirement
The amount of crop-available nitrogen that must be applied to achieve the economically optimum yield.

Denitrification
Microbial conversion of nitrate and nitrite in anaerobic soil to nitrogen gas and some nitrous oxide.

Deposition
Transfer of nutrients from the atmosphere to soil or to plant surfaces. The nutrients, mainly nitrogen and sulphur, may be dissolved in rainwater (wet deposition) or transferred in particulate or gaseous forms (dry deposition).

Digestate
Organic material produced by anaerobic digestion of biodegradable organic materials. May be separated into liquid and fibre fractions after digestion.

Dirty water
Lightly contaminated run-off from lightly fouled concrete yards or from the dairy/parlour that is collected separately from slurry. It does not include liquids from weeping-wall stores, strainer boxes, slurry separators or silage effluent, which are rich in nitrogen and regarded as slurries.

Economic optimum
Rate of nitrogen application that achieves the greatest (nitrogen rate) economic return from a crop, taking account of crop value and nitrogen cost.

Efficiency factor
Percentage of total nitrogen in a manure that is available to the crop for which the manure was applied. There are mandatory minimum values in NVZs for use when estimating the nitrogen availability of manures.

Erosion
Movement (transport) of the soil by running water or wind.

Eutrophication
Enrichment of ecosystems by nitrogen or phosphorus. In water, it causes algae and higher forms of plant life to grow too fast. This disturbs the balance of organisms present in the water and the quality of the water concerned. On land, it can stimulate the growth of certain plants, which then become dominant so that natural diversity is lost.

Excess winter rainfall
Rainfall between the time when the soil profile becomes fully wetted in the autumn (field capacity) and the end of drainage in the spring, minus evapotranspiration during this period (i.e. water lost through the growing crop).

FACTS
UK national certification scheme for advisers on crop nutrition and nutrient management. Membership is renewable annually. A FACTS Qualified Adviser has a certificate and an identity card.

Farmyard manure (FYM)
Livestock excreta that is mixed with straw bedding material that can be stacked in a heap without slumping.

Fertiliser
See Manufactured fertiliser.

Fluid fertiliser
Pumpable fertiliser in which nutrients are dissolved in water (solutions) or held partly as very finely divided particles in suspension (suspensions).

Frozen hard
Soil that is frozen for more than 12 hours. Days when soil is frozen overnight but thaws out during the day do not count.

Granular fertiliser
Fertiliser in which particles are formed by rolling a mixture of liquid and dry components in a drum or pan. Typically, particles are in the 2–4 mm diameter range.

Grassland
Land on which the vegetation consists predominantly of grass species.

Greenhouse gas
Gas such as carbon dioxide, methane or nitrous oxide that contributes to global warming by absorbing infrared radiation that otherwise would escape to space.

Green manure
See Cover crop.

Heavy metal
Cadmium, copper, lead, mercury, nickel or zinc. Elements that are potentially toxic to mammals above critical levels. Copper, nickel and zinc are required by plants in very small amounts.

Incorporation
A technique (discing, rotovating, ploughing or other methods of cultivation) that achieves some mixing between an organic manure and the soil. Helps to minimise loss of nitrogen to the air through volatilisation and nutrient run-off to surface waters.

Inorganic fertiliser
Manufactured fertiliser that contains only inorganic ingredients or urea.

Layer manure
Poultry excreta with little or no bedding.

Leaching
Process by which soluble materials such as nitrate or sulphate are removed from the soil by drainage water passing through it.

Ley
Temporary grass, usually ploughed up one to five years (sometimes longer) after sowing.

Lime requirement
Amount of standard limestone needed in tonnes/ha to increase soil pH from the measured value to a higher specified value (often 6.5 for arable crops). Can be determined by a laboratory test or inferred from soil pH.

Liquid fertiliser
See Fluid fertiliser.

Livestock manure
Dung and urine excreted by livestock or a mixture of litter, dung and urine excreted by livestock, even in processed organic form. Includes FYM, slurry, poultry litter, poultry manure, separated manures and granular or pelletised manures.

Macronutrient
See Major nutrient.

Maintenance application
Amount of phosphate or potash that must be applied to replace the amount removed from a field at harvest (including that in any straw, tops or haulm removed).

Major nutrient
Nitrogen, phosphorus, potassium, magnesium, sulphur, calcium or sodium that are needed in relatively large amounts by crops.

Manufactured fertiliser
Any fertiliser that is manufactured by an industrial process. Includes conventional straight and NPK products (solid or fluid), organo-mineral fertilisers, rock phosphates, slags, ashed poultry manure, liming materials that contain nutrients.

Manure
See Livestock manure and Organic material (manure).

Micronutrient
Boron, copper, iron, manganese, molybdenum and zinc, which are needed in very small amounts by crops. Cobalt and selenium are taken up in small amounts by crops and are needed in human and livestock diets.

Mineral nitrogen
Nitrogen in ammonium (NH_4) and nitrate (NO_3) forms.

Mineralisable nitrogen
Organic nitrogen that is readily converted to ammonium and nitrate by microbes in the soil, for example during spring.

Mineralisation
Microbial breakdown of organic matter in the soil, releasing nutrients in crop-available, inorganic forms.

Neutralising value (NV)
Percentage calcium oxide (CaO) equivalent in a material. 100 kg of a material with a neutralising value of 52% will have the same neutralising value as 52 kg of pure CaO. NV is determined by a laboratory test.

Nitrate Vulnerable Zone (NVZ)
Areas designated by Defra as being at risk from agricultural nitrate pollution.

Nitrogen uptake efficiency
Uptake of nitrogen from soil, fertiliser or manure expressed as a percentage of nitrogen supply from that source.

Nitrogen use efficiency
Ratio of additional yield produced to the amount of nitrogen applied to achieve that increase. Often expressed as kg additional yield per kg N applied.

Nitrous oxide (N_2O)
A potent greenhouse gas that is emitted naturally from soils. The amount emitted is related to the supply of mineral nitrogen in the soil. It increases with application of manures and fertilisers, incorporation of crop residues and growth of legumes. It is greater in organic and peaty soils than in other soils.

Offtake
Amount of a nutrient contained in the harvested crop (including straw, tops or haulm) and removed from the field. Usually applied to phosphate and potash.

Olsen P
Concentration of available phosphorus in soil determined by a standard method (developed by Olsen) involving extraction with sodium bicarbonate solution at pH 8.5. It is the main method used in England, Wales and Northern Ireland and the basis for the Soil Index for P.

Organic material (manure)
Any bulky organic nitrogen source of livestock, human or plant origin, including livestock manures, biosolids (sewage sludge), compost, digestate and waste-derived materials.

Organic soil
Soil containing between 10% and 20% organic matter (in this guide). Elsewhere, it sometimes refers to soils with between 6% and 20% organic matter.

Peaty soil (peat)
Soil containing more than 20% organic matter.

Placement
Application of fertiliser to a zone of the soil usually close to the seed or tuber.

Poultry manure
Excreta produced by poultry, including bedding material that is mixed with excreta, but excluding duck manure with a readily available nitrogen content of 30% or less.

Prilled fertiliser
Fertiliser in which particles (prills) are formed by allowing molten material to fall as droplets in a tower. Droplets solidify during the fall and tend to be more spherical and somewhat smaller than granules (see Granular fertiliser).

Readily available nitrogen
Nitrogen that is present in livestock and other organic manures at the time of sampling in molecular forms that can be taken up immediately by the crop (ammonium or nitrate, or in poultry manure uric-acid N). High in slurries and poultry manures (typically 35–70% of total N) and low in FYM (typically 10–25%).

Removal
See Offtake.

Run-off
Movement of water across the soil surface which may carry nutrients from applied manures or fertilisers. Water can also carry soil particles that hold nutrients.

Sand
Soil mineral particles larger than 0.05 mm.

Silt
Soil mineral particles in the 0.002–0.05 mm diameter range.

Slurry
Excreta of livestock (other than poultry), including any bedding, rainwater and washings mixed with it, which can be pumped or discharged by gravity. The liquid fraction of separated slurry is also defined as slurry.

SNS Index
Soil nitrogen supply expressed in seven bands or Indices, each associated with a range in kg N/ha.

Soil Index (P, K or Mg)
Concentration of available P, K or Mg, as determined by standard analytical methods, expressed in bands or Indices.

Soil mineral nitrogen (SMN)
Ammonium and nitrate nitrogen, measured by the standard analytical method and expressed in kg N/ha.

Soil nitrogen supply (SNS)
The amount of nitrogen (kg N/ha) in the soil that becomes available for uptake by the crop in the growing season, taking account of nitrogen losses.

Soil organic matter
Complex, variable fraction of the soil that consists of living, or once-living, materials within, or added to, the soil. These organic compounds, in various stages of breakdown (decomposition), range from undecomposed plant and animal tissues, to fairly stable brown or black material with no trace of the anatomical structure of the material from which it was derived.

Soil texture
Description based on the proportions of sand, silt and clay in the soil.

Soil type
Description based on soil texture, depth, chalk content and organic matter content.

Solid manure
Organic manure which can be stacked in a free-standing heap without slumping.

Target Soil Index
Lowest soil P or K Index at which there is a high probability that crop yield will not be limited by phosphorus or potassium supply. See Soil Index (P, K or Mg).

Tillage land
Land that is not being used for grass production and is sown with a crop.

Trace element
See Micronutrient.

Volatilisation
Loss of nitrogen as ammonia from the soil to the atmosphere.

Water-soluble phosphate
Phosphate, expressed as P_2O_5, that is measured by the statutory method for fertiliser analysis. Not necessarily a measure of available phosphate – high water solubility indicates high availability, but low water solubility does not necessarily indicate low availability.

Weathering
Breakdown of soil mineral particles by physical or chemical processes. Enhanced by variation in temperature and moisture. A significant mechanism for release of potassium from clay minerals.

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