Soil and agri-environment schemes: interpretation of soil analysis

The Environmental Stewardship Scheme has a number of management options for habitat re-creation and restoration. Some of these options require detailed information on the soils of the proposed sites to identify whether they are suitable and, if they are, to determine the most appropriate target habitats to aim for. This information note covers general interpretation of the results of soil analysis. Other information notes provide further guidance, including guidance on sampling methodology and soil texture.

Key points

- Standard soil sampling methodology and analysis is essential.
- Low soil phosphorus status is critical when trying to achieve botanical diversity.
- Soil nitrogen status is important on land undergoing reversion from arable to grassland.
- Knowledge of inherent soil type and soil pH will assist with determining an appropriate seed mix or target vegetation type.

Introduction

The application of lime, inorganic fertilisers and manures, combined with cultivation practices, have had profound effects on the soils of agricultural land in the UK.

Where sites are being considered for habitat re-creation or restoration under an agri-environment scheme, knowledge of the soil properties is very important. Such information helps with setting site objectives, and provides a valuable baseline against which trends can be judged and problems diagnosed.

Sampling methods

The reliability of analysis results is dependent on the accuracy of sampling. The correct sampling tool should be used and the correct number of sub-samples collected. Detailed guidance is provided in Technical Information Note 035, *Soil sampling for habitat recreation and restoration*.

Methods of analysis

Before interpreting the results it is very important to know which analysis methods were used and the units in which they are expressed. Most commercial laboratories measure pH, extractable phosphorus (P), extractable potassium (K) and extractable magnesium (Mg). (Note extractable nutrients were previously referred to as available nutrients). They do not usually measure soil nitrogen (N) though they may measure organic matter.

Soil pH is usually measured in water. It may be measured in calcium chloride (giving a value approx 0.6 of a unit lower) but this is usually converted to a water basis for reporting.

In the case of P, K and Mg the analysis uses chemical extractants to provide an estimate of the amount of the element in the soil that is available to plants, not the total amount which is very much greater. The main methods of analysing soil P and K are listed in Tables 1 and 2. The Modified Morgan method is generally used for soils in Scotland, but is not recommended in England and Wales.

Soil test results for P and K are reported as both a concentration and an index which covers a range of values. The concentration is usually expressed as milligrams per litre (mg/l). Parts per million (ppm) is comparable. Milligrams per kilogram (mg/kg)

First edition 21 February 2008

www.naturalengland.org.uk

may give misleading results if the soil is of low density such as peat.

Soil nutrients

Soil phosphorus (P)

Phosphorus is a major plant nutrient, although it is taken up in relatively small amounts compared with K and N. It has a major influence on grass growth, directly favouring grasses over broad-leaved species. Soils in the UK are naturally low in P and the main input is from fertilisers and animal dung.

The majority of soils that have grown arable crops, or that support grassland which has received high inputs of inorganic fertilisers or manures, have a moderate/high P status of Index 2 or more. P is a very insoluble and rather immobile element in soil, and is only leached out once it reaches excessive levels (index 5 or more). Once its status is raised it declines only very slowly, even in the absence of fertiliser additions. The effects of basic slag and superphosphate applied to land in the 1950s and 1960s, for example, may still be in evidence today.

Where the main objective is the development of botanical diversity, the site should have a low soil P status (Index 0 or 1).

The exception is where the soil or slope imposes high stress on plants by drought (indicated by very shallow soil or extreme stoniness) or water-logging, some level of botanical diversity may be attained even if the P status is high.

Phosphorus in run-off from agricultural land is an increasing environmental problem and is due mainly to erosion of soil particles, washing out of recently applied fertiliser/manure and leaching. This results in nutrient enrichment of water courses and water bodies, symptoms of which include algal blooms and loss of species diversity.

The P status of semi-natural, species-rich grassland is typically low (Index 0). P is considered to be the most important nutrient influencing sward diversity.

Table 1 Approximate equivalence of phosphorus extraction methods used in the UK

	Method			
	Olsen's [1]	Resin [2]	Modified Morgan [3]	
Index	mg/l[4]	mg/l	Status	mg/l
0	0 - 9	320 - 19	very low	0.5 < 1.8
1	10 - 15	20 - 30	Low	1.8 - 4.4
2	16 - 25	31 - 49	moderate	4.5 - 13
3	26 - 45	50 - 85	high	14 - 30
4	46 - 70	86 - 132	very high	>30
5	71 - 100	>132	very high	>30
6	101 - 140		very high	>30
7	141 - 200		very high	>30
8	201 - 280		very high	>30
9	> 280		very high	>30

[1] Sodium bicarbonate extract. [2] Anionic resin extract. [3] Ammonium acetate/acetic acid extract. [4] mg/l is in dry soil (rather than fresh soil or even soil solution).

Soil potassium (K)

Soil K is essential for efficient plant growth. It is derived naturally in soils from the weathering of clay-rich minerals, and clay soils are usually well supplied with K.

K is much more soluble than P and is subject to some losses by leaching, especially from sandy soils, but this is generally insignificant in relation to input from weathering and fertilisers. It is taken up by plants in much larger amounts than P.

Species-rich swards have a much wider range of soil K than soil P and K is widely accepted as being a less important soil nutrient when considering the suitability of sites for habitat re-creation or restoration.

Intensive grassland and arable soils are normally Index 2 or above, although on light, sandy soils K is rarely above Index 1.

On grassland where the K status is Index 0 low herbage yields are likely and it may be desirable to maintain K by the regular application of farmyard manure or, where permitted, inorganic fertiliser.

Table 2 Approximate equivalence of potassium extraction methods used in the UK

Method			
Ammonium Nitrate		Modified Morgan	
Index	mg/l	Status	mg/l
0	0-60	very low	<40
1	61-120	low	40-75
2-	121-180	moderate	76-200
2+	181-240		
3	241-400	high	201-400
4	401-600	very high	>400
5	601-900	very high	>400
6	901-1500	very high	>400
7	1501-2400	very high	>400
8	2401-3600	very high	>400

Soil nitrogen (N)

Nitrogen is normally the dominant nutrient determining herbage growth. The vast majority of N in the soil is bound up in organic matter. A small proportion is decomposed by soil micro-organisms each growing season, releasing mineral N (nitrate and ammonium).

Under old grassland, total soil N is usually high, often 1% or more since lack of cultivation allows the accumulation of plant material and manures. Following long-term arable cropping, particularly in the absence of animal manures and grass leys, N content will be considerably lower (see table 3). The exception is on peaty soils where N will remain high. A moderate or high total soil N content in an arable field suggests that it has received high inputs of animal manures (in which case its P and K status will also be high) or its history of cultivation is relatively short.

Soil N analyses

Total N (%): also known as Leco N, Dumas N or Kjeldahl N, which is available for plant uptake. This varies, depending on moisture and temperature, and is greatly increased by soil cultivation .

Values found in other soil analyses include:

- Organic matter (%): normally 12 to 17 times the total N content.
- Loss on ignition: can be converted to OM.

Mineral N (kg/ha): the nitrate and ammonium N content. A transient measure of immediately available N, not useful for our purposes.

Table 3 Guidance on thresholds for total N

	Total N (%)		
Land use	Low	Medium	High
Arable	<0.25%	0.25 - 0.5%	>0.5%
Long-term grass	<0.5%	0.5-1%	>1%

Total N is not usually determined in commercial soil analyses since it is not used directly for fertiliser recommendations. However it is very useful in judging the history of a field, and the likelihood of problems of low productivity. It is closely correlated with organic matter, and is cheap to measure.

On arable land which is being considered for the re-creation of species-rich grassland, the status of both extractable P and total N are important to consider. When sites with low N and moderate/high P are reverted to grassland, there is a high chance of white clover *Trifolium repens* growing vigorously. White clover seeds are often present in soil even after many years of arable cropping. Nitrogen fixation by clover also allows grasses to grow vigorously, and may present a higher risk of perennial weeds such as creeping thistle *Cirsium arvense*, broad-leaved dock *Rumex obtusifolius* and nettles *Urtica dioica* thriving. Such conditions make it very difficult for wildflowers and less competitive grass species to survive.

Arable sites targeted for creation of 'species rich' grassland should ideally have high total N and low P. However, in practice such sites are rare and sites with low P should still be selected even where soil N is low.

Magnesium (Mg)

Standard laboratory analysis often includes magnesium, which is important for animal health. Magnesium deficiency (commonly known as grass staggers or grass tetany) can occur in grazing animals when the Mg content of herbage is low. Magnesium content in plants is inversely related to K content, so that a high content of K depresses Mg. There is a greater risk of deficiency in spring when there is high uptake of K by plants. The risk of Mg deficiency can be reduced by providing a steady supply in the animals food or water, or as a long term strategy using magnesian lime. But high levels of Mg may reduce dietary availability of other nutrients. Seek professional advice if in doubt.

Table 4 Magnesium index system used in the UK

Magnesium Extraction Method: Ammonium Nitrate	
Index	**mg/l**
0	0-25
1	26-50
2	51-100
3	101-175

Nutrient stripping

With the exception of clay-rich sites, K can be readily reduced over a number of years by repeated removal of leafy crops, such as hay and particularly silage, which take up large amounts of K. On sites with high K status, K is taken up by plants in luxury amounts.

Reduction in soil P is more difficult to achieve. Uptake in herbage is low in relation to the size of the available pool of soil P. Regular cutting and removal of the herbage, combined with no fertiliser input, will have some effect, especially on thin, light soils. However changes will generally be very slow and take many years.

Because soil nutrients are evenly spread throughout the plough layer in arable fields (normally to a depth of 15-20cm), there is little that can be done to reduce P levels other than to physically remove the topsoil. However, this is expensive and is not recommended because it irreversibly reduces land capability and could potentially do great damage to underlying archaeological features. Minor re-profiling of the soil surface is possible on a very small scale, but should only be undertaken after a full assessment of potential impacts. If soil is stripped it should be reused and not dumped to landfill or regarded as waste.

Deep ploughing with conventional machinery has been found to significantly dilute soil nutrients in the short term, but the effects disappeared after four years. It is therefore not recommended.

Soil pH

Most soils in the UK are naturally acidic, due to natural soil processes and the acidifying effect of rainfall. Exceptions are naturally calcareous soils, for example those derived from limestone, chalk or calcareous boulder clay.

Under agricultural production, soil pH will normally have been raised by liming to pH 6.0-6.5. This maximises the availability of many nutrients and increases soil organism activity.

At very low pH (<4.5), aluminium becomes soluble which many species cannot tolerate. However, the availability of soil P is not strongly affected by pH.

Knowledge of the inherent soil texture and pH will assist with determining an appropriate seed mix or target vegetation type. Some species can only tolerate a limited pH range such as either very acid or very calcareous.

Table 5 Range of soil pH of grassland communities

Description	pH range
Acid	<5
Acid-neutral	5 - 5.4
Neutral (mesotrophic)	5 - 6.5
Calcareous	>6.5

It should not be assumed that all soils overlying chalk or limestone are calcareous. Their origin may be, for example, sandy/gravelly glacial drift or clay-with-flints which are naturally acidic. In chalk/limestone valleys and on footslopes, soils are often deeper with a pH of 6.5 or less and will support neutral rather than calcareous grassland.

Where the objective is re-creation of heath or acid grassland, a low pH is essential. When lime additions cease on soils which are naturally acid, pH will decrease over time but the rate and extent will vary greatly depending on such factors as soil type and depth, and amount of rainfall. Changes will generally be quickest on soils which are sandy and/or low in organic matter, and in areas of high rainfall. There have been attempts to reduce pH artificially, for example by adding sulphur and acidic plant materials such as bracken litter. These methods can be successful but they are expensive and may only be appropriate for small areas of high value sites. You are advised to seek professional advice if considering this option.

Soil texture

Soil particles vary tremendously in size. The main grades are clay, silt and sand sized particles. Soil texture describes the mixture of particle sizes within the soil. It has a major impact on soil physical, chemical and biological properties, for example drainage status, water availability and nutrient retention. Clay soils, for example, retain nutrients and water readily, and some release K continuously even when no fertiliser has been applied. Sandy soils have a lower capacity to retain K, although P may be higher than on clay soils.

Soil texture can be determined approximately by hand (Hand Texturing), or more accurately by Particle Size Distribution (PSD) analysis. For most soils there is a close relationship between PSD and hand texture and the latter is sometimes a better indicator of the 'workability' of the soil. For more information on soil textures see Technical Information Note 037.

Further information

This note does not supersede prescriptions in agri-environment scheme agreements. If there is any conflict between the information in this note and your agreement please contact your local adviser.

Natural England Technical Information Notes are available to download from the Natural England website: **www.naturalengland.org.uk**. For information on other Natural England publications contact the Natural England Enquiry Service on 0845 600 3078 or e-mail **enquiries@naturalengland.org.uk**.

This note has been developed from text previously published as a Rural Development Service Technical Advice Note.