European Fertilizer Manufacturers Association

Sustaining Fertile Soils and Productive Agriculture

Acknowledgements

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with technical assistance from Philippe Eveillard (UNIFA) and Christian Pallière (EFMA)

With contributions from

Roland Dudda (Linzer Agro Trade),
Wolfgang Hofmair (AMI),
Karl-Friedrich Kummer (BASF),
Joachim Lammel (Yara),
Richard Martin (Terra Industries),
Mogens Nielsen (Kemira Growhow),
Jens Lund Pedersen (Kemira GrowHow),
Jane Salter (AIC),
Krzysztof Wojdylo (Anwil),
Wolfram Zerulla (BASF).

Images from
BASF; YARA; ECOPT; Chafer Machinery; UK Environment Agency; Velcourt; Potash Development Association

The production of food and non-food crops, livestock farming and the management of the countryside are understood by farmers to be largely their responsibility. Those who provide them with inputs and advice are also fully aware that agriculture demands a high level of technical understanding combined with an appreciation of the complex integrated nature of farm and rural management. Over the past 50 years European agriculture has shown itself to be highly responsive to new scientific knowledge and to encouragement from governing authorities.

This publication sets out to describe some of the scientific principles which underpin good soil management, with particular reference to the maintenance of soil fertility and thus the ability to grow healthy and profitable crops. The increasing focus on the need to demonstrate good practice in all aspects of agriculture and countryside management is leading farmers and their suppliers to monitor actions and performance. This auditing of practices, the reviewing of results against benchmarks and the continual striving to improve on past performance is described as integrated farm management. Within this overall dynamic concept integrated nutrient management plays a key part. It has a significant responsibility for the sustainable management of soils to ensure their continued fertility and productive capacity, integrating this with minimising potential adverse environmental impact of agriculture.

Published by

efma
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Keynote Introduction

Farmers need inputs such as fertilisers, to sustain yields and to produce good quality crops. Yet, inappropriate use of fertilisers can lead to pollution of the environment, in particular water, through nutrient leaching or run-off. By recognizing the needs of agriculture on the one hand, and its impacts on the environment on the other, the Community aims to achieve an acceptable balance between competitive agricultural production and environmental protection.

In order to contribute to this aim, the Common Agricultural Policy (CAP) has progressively been adapted. The three major reforms of 1992, 1999 and 2003 have made agriculture more sustainable, both in economic and in environmental terms. The reforms of the tobacco, hops, olive oil and cotton sectors in 2004, the rural development policy in 2005, and of the sugar regime in 2006, are the latest steps in this direction.

The key measures of the first pillar of the CAP (market support and direct payments) are the Single Farm Payment, which allows the decoupling of income support from production; cross-compliance, which makes the full granting of the direct payments conditional on the respect of statutory management requirements (including the Nitrates and Groundwater Directives) and on the requirement to keep all farmland in good agricultural and environmental condition. Moreover, the reform of 2003 makes the introduction of farm advisory services mandatory for Member States from 2007 onwards. They are meant to help farmers respect their cross compliance obligations and improve their farm management.

As regards the second pillar of the CAP, we have now a new set of rules for the period 2007-2013, which streamlines and consolidates the menu of rural development measures for which Member States can draw EU funding. Thus, the new Rural Development Regulation ensures the continuity of current support measures, e.g. for training, modernisation, high quality production, environmentally friendly land management and landscape stewardship. In some cases, measures or the conditions linked to them have been changed, partly to simplify their implementation, but partly also to implement them in a more targeted way. Only few new measures have been added to complement the existing menu, e.g. payments linked to the Water Framework Directive support to promote cooperation and innovation or aids for the establishment of agro-forestry systems.

I am convinced that the principles of the recent CAP reforms provide the right framework for the sustainable development of EU agriculture. The focus is now on making the best use of the opportunities offered by these reforms. Furthermore, where this makes sense, we also have to extend these principles to the sectors that have not yet been reformed: wine and fruit and vegetables.

I would like to add that, in parallel to legislative actions, voluntary initiatives are also an important tool to help farmers achieve the goal of greater sustainability. In this context, the publication of EFMA's booklet on good integrated nutrient management is most welcome.

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1. Introduction

EFMA is a pan-European organisation providing a resource both for its Members and for those who organise and regulate European affairs. This two-way communication and discussion extends through its Members between the grass-roots of European agriculture and the highest levels of national and European governance.

Good agricultural practices.

EFMA understands and acknowledges the importance of good practices for fertilizer production, distribution and usage as part of the industry's product stewardship. In this publication a clear analysis of good agricultural practices (GAP) is presented, which EFMA supports and promotes for the use of its products. The fertilizer industry has over recent decades funded a considerable volume of research into efficient and environment-compatible soil management and crop production. In addition it has developed and introduced many of the tools which assist the farmer to achieve good practice. Good nutrient, soil and environmental practices are a core part of the integrated farm management approach now adopted by leading farmers throughout Europe.

Integrated farm management.

The basis of an integrated approach is that it identifies all the aspects of farm management, including the soil, the farm habitats and the wider environment, crop production, animal health and welfare, manures and fertilizers, crop protection, and employee and local social issues. The integrated farmer finds and develops an integrated set of good practices for these areas, which he implements on his farm. Most importantly, and on a continuing basis, he measures and records his actions and their effects, so that his plan for the following season will encourage improvements over past practices. He will carry out an audit of all aspects of the farming activity, and will be in a position to compare and benchmark his performance against that of his neighbours and peers. It is essentially a demonstrable and dynamic approach towards 'better' agricultural practices.

Training session on farm

This book identifies the issues which relate to nutrient management and illustrates the way in which the fertilizer industry is a significant provider of science-based information and tools to assist the farmer in the achievement of his GAP goals. It includes profiles of different farm types by farmers from across Europe who are working to good practices. These farmers are using a range of tools which the fertilizer industry has helped to develop and make available.

The way forward.

EFMA and its Member companies see clearly that the continuing implementation of good practice protocols, ideally using integrated management practices, is a proven and viable way towards striking an acceptable balance between the needs for agricultural production and for a sensitively managed environment. EFMA believes that GAP, in the self-monitoring framework of integrated farming, offers a robust and workable model for nutrient management in European agriculture which takes account of the requirements for the Nitrate Vulnerable Zones (NVZs), the management of soils and for the Water Framework Directive.

Farmers make many decisions.

Farmers carry a large burden of technical and practical responsibilities, both economic and environmental, in the management of their crops, livestock and the overall farm business.
In developing his framework for good agricultural practice in plant nutrition, the farmer has many issues to consider and questions to answer, and all these within a framework of climatic and other uncertainties. Some of these questions are shown in the box.

It is clear that there are many complex and technical issues which have to be addressed by the farmer. This booklet outlines some of the science and the guidelines which are available. Much of this is provided by those in the fertilizer industry as direct recommendations and advice, and through the use of tools which the industry and others provide.

This booklet introduces three aspects:

In chapter 2 'Understanding crop nutrition' provides the basic information necessary for good practices.

Secondly 'Crop nutrition using manures and fertilizers' is described in chapter 3, beginning with consideration of the management of each nutrient according to the needs of the crop at the field scale, leading to the recycling of manures or other organic wastes and the balancing use of fertilizers and concluding with an appraisal of integrated farm management as a vehicle for the delivery of good practices at the farm scale.

Thirdly 'Crop nutrition in river basin management' (chapter 4) introduces the need to consider risks beyond the farm boundaries and considers integrated management as the framework for economic and environmental progress at the river basin scale.

Some of the complex and technical questions a farmer has to ask, and to which he must find answers:

- What are the plant nutrients that I have to consider and what are the critical features of each that I must take into account?
- How do I know what reserves of nutrients I have in my soils?
- How do my crops differ in their needs for nutrients, and how much do they remove from my soil? Do they all behave in the same way?
- What are the key points I must understand about my soil and how do I ensure its continuing good condition? What can I do to improve it?
- How can I judge whether any of my fields need lime?
- How can I time the application of fertilizers most precisely? How should I integrate my fertilizer policy into my crop rotation?
- How do I find out whether my crops or animals need any micronutrients or trace elements? How should I apply them if needed?
- How do I integrate the nutrients in my manures into the system? What are the nutrient values of the manures and how should I store and apply them?
- What restrictions apply within a Nitrate Vulnerable Zone and how do I manage my manures and fertilizers to comply? How do I calculate whether I have the right number of animals?
- If I expect a higher or lower than average yield, judging by previous crops, should I alter the amount of fertilizer I apply?
- What is the best way to minimise any loss of nitrogen from my fields over the winter?
- How do I reduce the risk of polluting the streams on my farm? What is the best way to encourage a variety of wild species of plants and animals in my field boundaries?

2. Understanding crop nutrition.

This section describes in some detail the science and technology which underpin good decision-making in the context of crop nutrition. The subsections describe firstly the needs of plants, then the functions of the soil in supporting plant growth and providing nutrients, and conclude with an outline of the practical issues of land use and management.

2.1. Plant nutrition and nutrients.

The basis of food production.

It is remarkable to consider that, with the exception of some microbes, plants are the only net producers in our biological system. As they grow, they fix the energy and synthesise all the building blocks humans and animals need for life. By 'trapping' the energy from solar radiation and transforming it into the chemically bound energy stored in carbohydrates and fats and by arranging chemical elements into proteins and vitamins, plants enable higher living beings to exist. In this basic fixation of light energy, the green plant uses just carbon dioxide and water as ingredients to produce sugar - a process known as photosynthesis.

Few but essential nutrients.

However, at least thirteen more chemical elements are indispensable to all plants to enable them to construct themselves and to function: to germinate, grow, photosynthesise and be fertile. These mineral elements are termed essential plant nutrients. For some species but not all, four more elements are vital (see Table 1). Each of the nutrients has distinctive features that enable it to fulfil its particular function in the metabolism of plants; no other element can replace it. Irrespective of whether they are required in large or small quantities, each element is equally essential to the proper functioning of the plant. Table 2 shows examples of the amount of nutrients removed with the harvest of some crops. The plant will normally obtain them from the soil through its roots, but if there is not enough of any one of these elements the metabolism of a plant will break down at a certain point of development and healthy growth, normal yield and good quality are no longer possible.

Table 1:
Non-biotic[#] plant growth factors

CLIMATIC FACTORS

energy factors
- light
- temperature

material factors
- carbon dioxide
- oxygen
- water

ESSENTIAL MINERAL NUTRIENTS

for all species
- nitrogen
- phosphorus
- potassium
- calcium
- sulphur
- magnesium
- iron
- manganese
- zinc
- copper
- boron
- molybdenum
- chlorine

for some species
- cobalt
- silicon
- nickel
- sodium

[#] Biotic growth factors for example are the genotype of the plants, pests and diseases

Balance of all nutrients.

In the middle of the 19th century Dr Justus von Liebig realised that each of the plant nutrients was equally essential and that even a surplus of all other elements could not compensate for a deficient one.

Table 2:
Amount of plant nutrients in various crops at harvest.

CROP		WHEAT		POTATO	SUGAR BEET
Yield		Grain 8 t/ha	Straw 5 t/ha	Tubers 35 t/ha	Roots 50 t/ha
Nutrient		**kg/ha**			
Nitrogen	N	150	25	125	85
Phosphate	P_2O_5	65	16	50	45
Potash	K_2O	50	70	210	230
Calcium	Ca	5	16	8	25
Magnesium	Mg	12	5	15	25
Sulphur	S	10	9	10	8
		g/ha			
Boron	B	40	25	55	350
Copper	Cu	40	25	40	80
Iron	Fe	800	250	310	300
Manganese	Mn	320	200	80	230
Molybdenum	Mo	5	2	3	6
Zinc	Zn	300	95	120	300

These amounts of nutrients will be removed with the yield. Non-harvested parts of the crop, e.g. roots, stubble and leaves, contain additional plant nutrients. The maximum quantity of nutrients taken up by the crop at the peak of its growth is considerably higher than the figures given here.

He thus formulated his 'law of the minimum': the least available nutrient limits the growth of a plant (Figure 1). Terms which classify the elements into primary, secondary and micro nutrients (for example) do not therefore describe their order of importance but refer to the quantities plants need of each and to the probability of shortages. During growth, plants require a permanent availability of all the nutritive elements, in proportion to their actual needs. The daily uptake depends on the rate of formation of new tissue and on the type of tissue being built. At full growth one hectare of wheat can take up 4 kg N, 2 kg P_2O_5 and 6 kg K_2O per day. The rate and the ratio at which nutrients are needed changes over the life cycle of a plant (Box 1, overleaf).

Figure 1:
The shortest stave represents the yield-limiting nutrient.

(Justus von Liebig 1803-1873)

Nutrients from the soil solution.

Plant roots take up mineral nutrients as ions, e.g. NH_4^+, $H_2PO_4^-$, K^+, Mg^{2+}, SO_4^{2-}, dissolved in the soil solution, irrespective of whether they originated in manures, composts or mineral fertilizers. But as the concentration of these elements in the solution is seldom identical to its actual needs, the plant is equipped with mechanisms to absorb selected ions actively and to refuse others. The nutrient content of the soil solution is replenished in different ways. As water is also taken up, there is a flow towards the roots bringing the dissolved ions with it.

In addition the continuing uptake of certain ions lowers their number in the vicinity of the roots and a concentration gradient arises. This is compensated by diffusion of these depleted ions towards the roots.

Almost all plants species have means to mobilise mineral nutrients not dissolved in the soil solution. Root tips, the preferred place of nutrient uptake, have root hairs 1 to 2 mm long to increase the contact with a larger soil volume and to excrete organic compounds, particularly acids, to solubilise nutrients and make them plant-available.

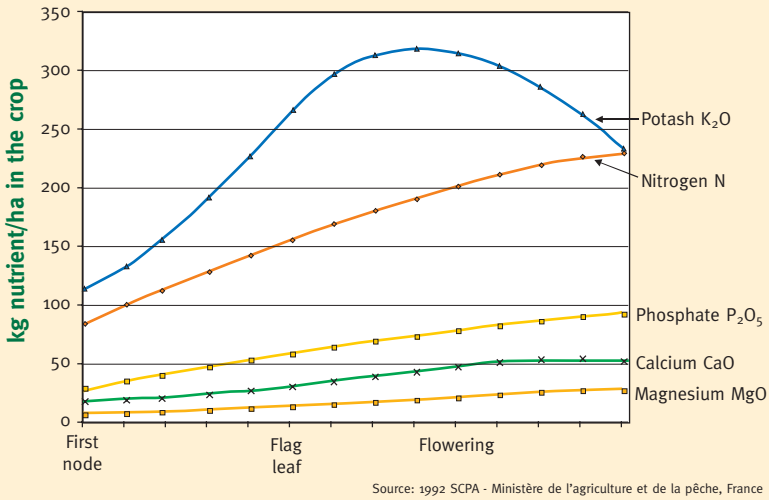
Nutrients fixed to mineral soil particles or in organic sources such as slurry, manure or compost can experience a considerable time lag before they become plant-available. Because mineralisation is a biological process in soils and the activity of the mineralising microbes depends on temperature, humidity and acidity of the soil, it is difficult to predict the time and rate of release of organically-bound nutrients.

Different root systems.

Under the pressure of millions of years of competition some plant species developed special tools to increase their efficiency of nutrient uptake. The most obvious is an extensive root system. Rooting depth and density of roots differ significantly between species. A wheat crop is very efficient at recovering nutrients, having an incredible total of up to 30 km of roots per square metre of soil area, and roots down to one to two metres deep. Vegetables such as spinach or radish have a root system of only 2 km/m² and which hardly goes deeper than 15 cm.

Box 1:

Nutrient uptake and dry matter formation of winter cereals. The uptake pattern of nutrients differs: whilst the amount of potassium in the crop reaches its high maximum at the end of vegetative growth, nitrogen and phosphate are accumulated until maturity.



Source: 1992 SCPA - Ministère de l'agriculture et de la pêche, France

Symbiotic arrangements.

Several plant species live in symbiosis with fungi, so-called mycorrhizae, on the roots. While the fungi feed on organic compounds excreted by the roots, they supply their host with mineral nutrients from the soil beyond the reach of root hairs. Another example of symbiosis is that of nitrogen-fixing bacteria living in specific nodules on the roots of leguminous species. In exchange for assimilates, the microbes fix nitrogen from the air and deliver it to the plant's root. However such plant species expend a substantial proportion of the energy fixed during photosynthesis on their symbiotic partners: up to 30% on mycorrhizae and up to 50% on nitrogen fixation.

Most nutrients are not in solution.

In the soil, only a very small proportion of the total plant nutrients are actually dissolved in the soil water. Most of the nutrient is stored in readily available or slowly accessible 'pools' (see Figure 2). The most plant-available nutrient reserves are those adsorbed to the surface of the solid soil particles (e.g. clay or humus) or bound in easily degraded organic material. Some precipitated minerals may also become redissolved by weak acids excreted from the roots. A proportion are incorporated in soil minerals and permanent humus and will not become available during the growing season. They may be released only after years or decades, if ever.

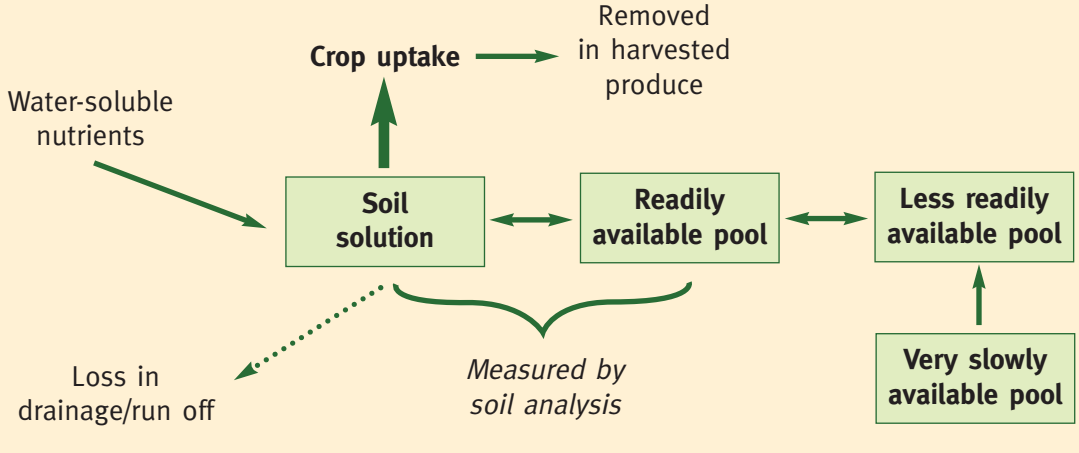
Historical systems unsustainable.

The nutrient content of an agricultural soil depends on its history (e.g. parent rock, deposition of external material, build-up of humus/organic matter, nutrient losses by leaching etc.) and on changes caused by man. Up to about a hundred years ago the use of land for farming generally resulted in a depletion of plant nutrient reserves in the soil. Prior to 1900 it was almost impossible for farmers to return to the land the quantity of nutrients removed in their harvested crop. The development of a better understanding of plant nutrition since the middle of the 19th century has led to the development and production of mineral fertilizers, which enable the farmer to apply sufficient nutrients to maintain the fertility of the soil.

Fertilizers restore soil fertility.

Not only could the nutrients taken from the soil reserves during the previous centuries thus be replaced, but it was also possible to add nutrients as necessary to ensure that the levels in the soil were sufficient for crops to grow without being limited by nutrient deficiencies. Building up from low soil fertility is quite an investment and in most European countries it took farmers well into the 1980s before the nutrient reserves in most of their soils had reached an appropriate level, which had been determined from decades of scientific work.

Figure 2:
A representation of the concept of 'pools' of reserve of nutrients such as phosphorus and potassium in the soil.



Nutrients held in soil.

Depending on the nutrient, soils have different storage capacities and processes. In Europe the main soil reserves of nitrogen and sulphur are in long-term organic matter which can be slowly mineralised to ionic forms such as ammonium (NH_4^+) nitrate (NO_3^-) and sulphate (SO_4^{2-}). These are forms in which plants take up the nutrients and in which they are applied as fertilizers. However negatively charged anions are not well retained in soils, and if not taken up by plants can be leached from soil if drainage occurs after rainfall.

The exception are the phosphate anions ($H_2PO_4^-$ or HPO_4^{2-}), which readily react with metallic cations in the soil to form precipitates and thus are extremely immobile in soil.

Cation-forming nutrients (NH_4^+, K^+, Mg^{2+} etc.) are adsorbed onto the surface of the negatively charged clay and humus particles and are not therefore liable to significant loss by leaching (Figure 4).

Loam soils by definition have a balanced content of sand, silt and clay; they have about 2-3% organic matter and have a good capacity for holding water and nutrients (see Figure 3). Free-draining sandy and shallow soils, and also acid soils, are less able to retain nutrients; in most alkaline soils the plant-availability of the majority of nutrients is reduced due to the high pH (see Figure 5 on page 14).

Figure 3:
The main components of a clay loam soil.

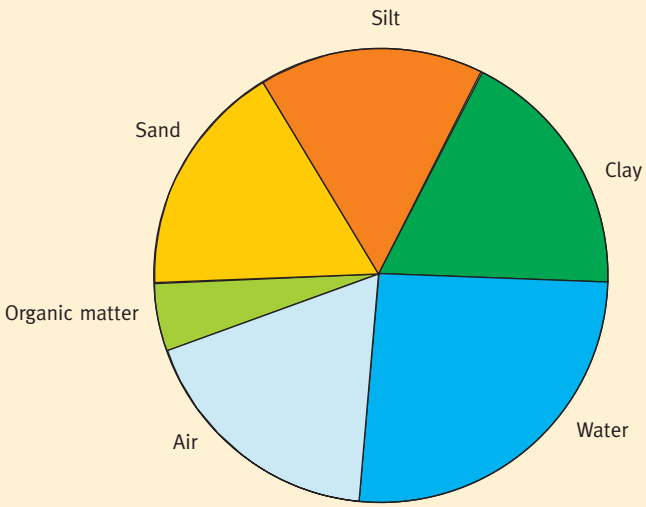
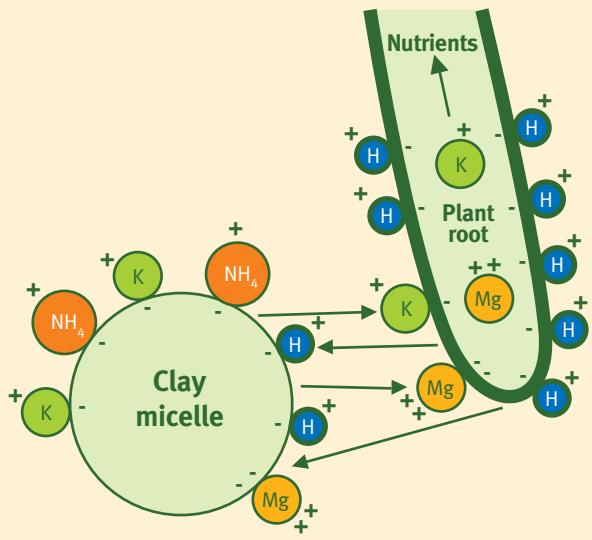


Figure 4:
Schematic illustration of the transfer of positively charged nutrient cations from the negatively charged surfaces of the clay particles to a nearby plant rootlet, so-called 'cation exchange' (after Courtney and Trudgill, 1976)



2.2. Soil management in interaction with plant nutrition.

Soil is the biologically active upper skin of the earth's crust where the mineral interior of our planet mixes with the living organisms on its surface. For plants the soil offers physical support and acts as a store for water and nutrients. Because plants cannot move, they depend entirely on the soil on which they are growing for all their nutrient supplies. High water tables, high proportions of gravel, compacted layers or shallow soils on infertile subsoil reduce the soil volume usable by the roots. Given sufficient water, a soil is considered fertile when it allows plants to grow to their genetic potential. This is achieved when the plant-available supply of each nutrient is high enough and when the soil structure allows the roots to grow and exploit the entire soil volume.

Good soil structure promotes soil life and root growth.

Soil structure describes the distribution of solid material, air and water in a soil, the size and shape of soil aggregates - 'crumbs' - and its resistance to deformation. Under natural conditions soil structure develops and maintains itself depending on soil type, climate and vegetation through the activities of

the soil flora and fauna (the soil biota), especially earthworms. Agricultural soil requires maintenance and care. About 35 to 60% of the soil (volume) consists of pores. The fine cavities (capillaries) are normally filled with water, whereas air circulates in the larger pores and supplies oxygen to the soil biota, including plant roots. A well-structured soil can absorb substantial amounts of rain without significant surface run-off which could lead to erosion and flooding. Soil with poor structure is dense with little pore volume which, when loosened mechanically, 'slumps' readily under pressure or rainfall. On soils with a fragile structure heavy rainfall often leads to a puddled surface which seals off the soil. This reduces the exchange of air and inhibits normal soil life and root activity.

Soil management to aid nutrient uptake.

To secure good rooting conditions farmers work the soil by cultivating the upper layer as necessary and loosening any compacted subsoil. Ploughing is carried out to destroy weeds and to bury their

seeds and diseased material deeply, to incorporate the residues of the previous crop and to loosen the soil. The cultivated layer, richer in nutrients and organic matter than the subsoil, contains the main reserve of nutrients for the crop. Generally speaking the depth of this layer was increased from 15-18 cm to 25-30 cm as a result of the change from cultivating using animals to using tractor-drawn implements. Thus the easily-rooted nutrient-enriched layer was almost doubled in volume, allowing

today's high yielding crops to obtain the nutrients they require without having to increase the concentrations in the soil.

Alongside traditional ploughing, systems of minimal soil cultivation have developed on certain soil types and for some crop rotations. The soil is worked on the surface only, just to incorporate some of the residue, the rest being left on the surface as a mulch. Within a few years the undisturbed soil develops a stable structure with good conditions for root growth.

Soil organic matter feeds microbes in the soil.

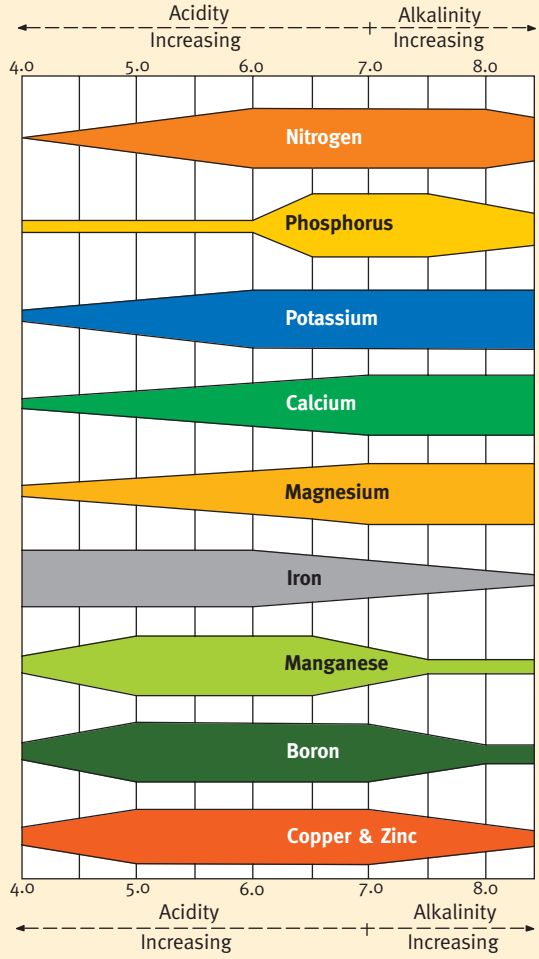
Soil organic matter plays a vital role in soil fertility. Organic material added to soil is food for the living soil microbial population, which only accounts for about 2-5% of the total organic matter in soil. However, an active population of soil microbes promotes soil fertility. They break down added organic material, for example from the roots and residues of crops or from manures, releasing plant nutrients and producing soil organic matter or humus. Humus stabilises soil crumbs composed of mineral particles so improving soil structure. A good structure ensures the right proportion of voids of different sizes that hold water and air, both essential for the roots to function. It also improves root growth to find nutrients and workability of the soil to produce good seedbeds. The amount of organic matter in soil depends on:

- the input of organic material and its rate of decomposition;
- the rate at which existing soil organic matter decomposes;
- soil texture;
- climate.

These factors interact so that soil organic matter changes towards an equilibrium value that depends on the farming system and soil type. Thus for any one farming system the equilibrium value will be larger on a clay soil than on a sandy soil and for any one soil type it will be larger under permanent grassland than under continuous arable cropping.

Optimum soil pH improves nutrient availability.

Figure 5:
Influence of soil pH on plant nutrient availability: the thicker the bar the more available the nutrient.



On heavy non-calcareous soil the regular application of lime helps to stabilise the soil structure. Calcium ions dehydrate the clay particles and make them cling together, thus the crumbs persist when they get wet and air spaces do not break down so easily when pressure is put on the soil. In addition liming helps to keep the soil acidity in the preferred range of pH 6 to 7. This is favourable not only for a diverse soil life but also to maintain the nutrients in a plant-available chemical form. At higher pH most of the nutrients precipitate and become difficult to absorb (Figure 5). This is why trace element deficiencies in plants often are pH-induced. But low pH also is unfavourable to crops because toxic elements such as aluminium become more soluble and hamper the uptake of the nutrients.

Variability in soils is often indicated by differences in colour.

Soil variability requires field or site-specific management.

On a farm, or even in a single field, the quality of soil may change over a short distance. Most soils have been translocated during their development which often causes segregation of the soil particles according to their size. Running water may have deposited gravel and sand in one place and deposited mineral-rich clay in another.

An uncultivated field margin between the farm crop and the hedgerow encourages biodiversity and wildlife.

Fine particles tend to be washed down a slope leaving behind a thinner soil layer containing coarser sandy material at the hill top. This has to be considered in the management of plant nutrition. The yield potential will be different and so the need to replace nutrients removed at harvest will also be different. The ability of the soil to retain and to supply plant-available nutrients will vary spatially and therefore specific rather than general nutrient management will be required. Areas at risk of erosion may need to be managed differently. A farmer will be aware of the variability of his soils and should know their particular demands.

Legal obligations.

In addition, legal obligations can introduce certain limitations in the handling and use of nutrients. Water protection zones, riparian strips and vulnerable zones as defined according to the Nitrate Directive may need separate treatments.

2.3. Land use and crop rotation.

A feature of agriculture is the variety of farm size, soil type, climate, crop species, livestock type and number, mechanisation, use of fertilizers and other inputs and general intensity of management. Two distinct categories of farms are those with, and those without, livestock. Livestock produce manures that are valued for the crop nutrients they contain.

The nutrients in manures may be retained on the farm in which case their application needs to be integrated with that of fertilizers. Sometimes, where the number of livestock is high and land is limited, manures are exported to other farms which have mainly arable cropping.

Different intensities of nutrient cycling on grassland.

Livestock enterprises based on grass and forage crops vary in their intensity of management: at one extreme is sheep production on hill land and at the other is dairy production with a stocking rate of around 2 cows/ha. The more intensive enterprises have a large requirement for nutrients but also produce large amounts of manures that contain nutrients. Over the years, nutrients can accumulate in the soil on these farms and can be released in significant amounts in plant-available forms through mineralisation. There can be a large release of plant-available nitrogen (N) where long-term grassland is ploughed for re-seeding or conversion to arable cropping.

Intensively managed grassland therefore presents some special issues for nutrient management.

Residues can provide nutrients for the following crop.

There are special issues too in arable cropping, where crops are established annually and the soil is disturbed by cultivations. Crop species vary in their nutrient requirements and in the quantities of nutrients removed at harvest. There also are differences in the amount and composition of different crop residues (see Table 3). Some, such as cereal straw, contain a high proportion of carbon and their incorporation into the soil can cause the temporary immobilisation of mineral N. Some additional N may be required to assist in the microbial decomposition of these residues. Others, such as those of field vegetables, decompose rapidly in the soil and are relatively immediate sources of N and other nutrients. In this case, fertilizer applications for the following crop must be adjusted to take account of the nutrients released from the residues.

Table 3
Example of guidelines for calculation of phosphate and potash removal by crops (kg nutrient per tonne of fresh material, UK standard data).

		kg/t of fresh material	
		P_2O_5	K_2O
Cereals	grain only	7.8	5.6
	grain & straw		
	winter wheat/barley	8.6*	11.8*
	spring wheat/barley	8.8*	13.7*
	winter/spring oats	8.8*	17.3*
Oilseed rape	seed only	14.0	11.0
	seed & straw	15.1*	17.5*
Field beans	seed only	11.0	12.0
Potatoes	tubers	1.0	5.8
Sugar beet	roots only	0.8	1.7
	roots & tops	1.9	7.5
Grass	fresh grass @ 15-20% DM	1.4	4.8
	silage @ 30% DM	2.1	7.2
	hay @ 86% DM	5.9	18.0

* Offtake value is per tonne of grain or seed but includes nutrients in straw.

Crop rotations for the efficient use of nutrients.

Arable crops are often grown in rotations where successive crops are of different species. Crop rotations were developed originally in the eighteenth century to conserve and maintain soil nutrients; clovers and other legumes were included to add nitrogen to the soil.

Today, the main reason for rotating crops is control of pests and weeds because changing the crop species restricts opportunities for specific pest and weed populations to develop. Nevertheless, crop rotations still affect nutrient use because crop species differ in their nutrient requirements. Some species such as peas or beans have no, or very little, need for added N. Others, like oilseed rape and high-yielding cereals, require in total perhaps 300 kg N/ha but extract up to 100 kg N or more from mineralisation of crop residues and organic matter in the soil. Some such as lettuce have a shallow root system and can exploit only around 20 cm of soil. Others like sugar beet have roots that extend to 2 m or more and can exploit nutrients in the sub-soil. All these differences between crop species must be taken into account when planning fertilizer use.

Soil cultivation stimulates mineralisation of soil nitrogen.

The timing and type of cultivations can affect nutrient release in arable soils. Generally, mixing soil and air when soil temperature is above around 4°C promotes mineralisation of organic N. Ploughing tends to be most effective at mixing soil and air so will result in greater mineralisation than will minimal cultivation techniques. If soil is cultivated in late summer or early autumn, the N released will be at risk of loss by leaching over winter. In contrast, leaving land uncultivated over winter and using minimal cultivation in spring will tend to conserve soil organic N. Cultivations therefore need to be planned together with fertilizer use to ensure the best use of nutrients.

Recycling mineral nitrogen with crops in the autumn.

Establishing a crop like winter cereals or winter oilseed rape in the autumn will help to minimise the risk of N loss by leaching. These crops take up significant quantities of the N which has been mineralized after harvesting the previous crop, and so reduce the amount remaining at risk in the soil. Alternatively, a 'cover crop' such as mustard or Phacelia can be sown in autumn to take up the mineral N in the soil. These crops are incorporated by cultivations in spring and their N content returns to soil in organic form.

Perennial crops.

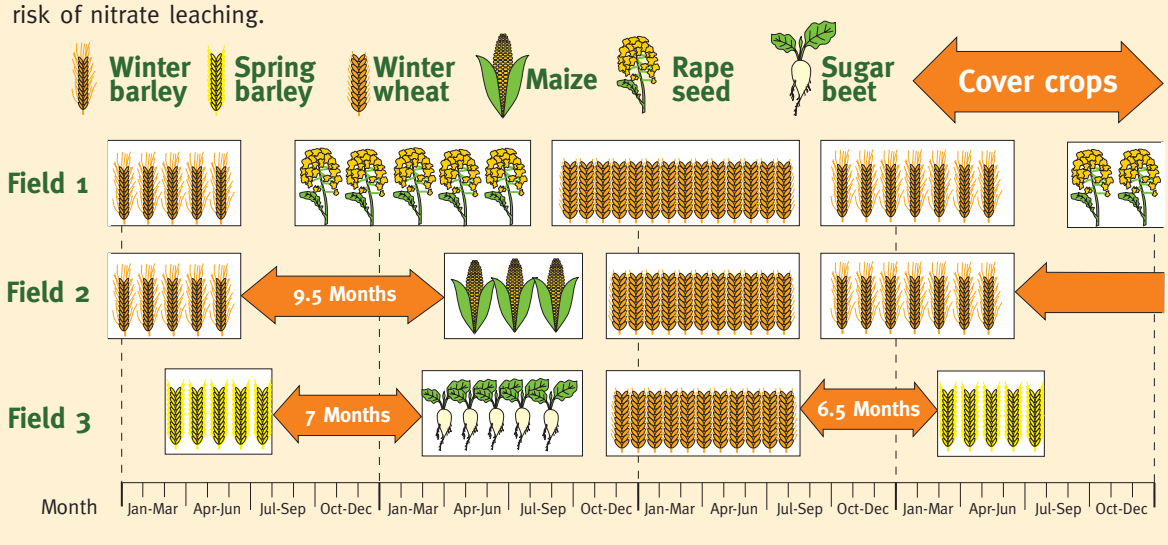
Perennial crops such as soft fruit, top fruit and nuts may have a relatively large nutrient requirement at establishment but a lower requirement in following years. Some of the nutrients taken up by these crops return to the soil as leaves die in autumn. Grass may be grown between the rows of perennial crops and this will affect nutrient cycling.

Co-ordinated management to minimise nutrient losses.

The behaviour of different nutrients in the soil in response to methods of land use and management must be taken into account. The plant-available forms of N and sulphur (S) exist mainly in the soil solution and are highly mobile; these nutrients can be easily lost by leaching during winter. In addition, some N can be lost to the air as nitrogen oxides or as nitrogen gas through denitrification when the soil is wet. Because of their mobility these nutrients must be applied annually to meet the needs of the current crop. Other nutrients including phosphorus (P), potassium (K) and magnesium (Mg) are mainly adsorbed on clay particles or organic matter and are much less mobile. Loss by leaching is minimal and there is no loss to the air. Consequently, applications can be made on a rotational basis and if too little or too much is applied, this can be corrected by adjusting applications in later years.

Box 2: Crop rotation and soil coverage

An illustration of the periods during which the land is growing crops over the rotation and the opportunities for the use of 'cover crops' during periods when there is no crop in the field. Growing a crop or cover crop protects the soil from erosion during heavy rainfall events and helps to minimise the risk of nitrate leaching.



3. Crop nutrition using manures and fertilizers.

This section deals with the practical management of plant nutrition. The first requirement for the farmer is to maximise the recycling and utilisation of the nutrients in manures, which have to be considered as available resources and not as problematic wastes. With an understanding of nutrient behaviour and reserve levels in soils together with knowledge of the nutrients available from on-farm manures, the farmer is able to calculate the quantity of manufactured fertilizers which may be required to make up the needs of his crops and grass. This section examines the different groups of nutrients according to their characteristics and to crop needs, and then assesses the management of organic manures in more detail.

3.1 Management of nutrients.

3.1.1. Mobile mineral elements in soil (nitrogen, sulphur).

Soil nitrogen (N) and sulphur (S) exist in the upper soil layer in organic and mineral (inorganic) forms. The total amount in most arable soils ranges between 3,000 to 10,000 kg/ha for N and 500 to 2,000 kg/ha for S, with even greater amounts being found in grassland soils. Usually at least 90-95% of this total soil N and soil S is in the organic form and is unavailable to plants, with about 2% of the organic N being converted each year to mineral forms by microbial action (i.e. being mineralised). From a plant nutrition point of view only mineral N and mineral S are important, because it is only in these forms that the plant roots can take up these nutrients. Mineral N occurs in two different forms in the soil: ammonium-N and nitrate-N. Ammonium-N (NH_4^+) is less mobile and can be fixed to clay minerals. However, this ammonium-N is rapidly converted into nitrate-N (NO_3^-) by soil microbes at soil temperatures above 3 to 5°C (nitrification) unless a specific nitrification inhibitor has been added. As a result nitrate-N is normally the predominant mineral N form in soil during the growth period of crops.

Highly mobile nutrients.

In contrast to most other soil nutrients, mineral N as nitrate and mineral S as sulphate (SO_4^{2-}) are highly mobile in the soil. Both of these nutrients are in the soil solution and neither is fixed to organic matter or to clay minerals. This high mobility and the interaction between the organic and mineral forms result in specific management guidelines for these nutrients, which differ considerably from those for other nutrients.

Nitrogen is the plant nutrient that most frequently limits crop production and has highest impact on yield and quality, and potentially on the environment. Crop requirement for S is less than that for N and deficiencies have developed only recently in Europe as atmospheric pollution has decreased. Consequently, far more effort has been spent on developing recommendations for fertilizer N than for fertilizer S.

Nitrogen deficiency on spring barley.

Under- as well as over-fertilization with N, organic or manufactured, will result in economic loss for the farmer due to reduced yield and quality of the crop. The economically optimum amount of fertilizer N is that which will give the best financial return based on crop and fertilizer prices. From an ecological perspective it is important that the grower makes the correct decision on how much and when to apply N to each crop because applications greater than crop requirement, or at inappropriate times, can impact on the environment through leaching of unrecovered nitrate.

Manures and fertilizers make up the difference.

The role of manure and fertilizer N application is to fill the gap between the requirement of the crop and the supply of N from other sources in the soil. Crop N uptake depends on the yield and its N content. Unfortunately both N uptake by a crop and soil N supply vary from field to field and from year to year. Final yield for a particular crop is difficult to predict and can vary within, as well as between, fields. The main reason for yield variability between years is the changing and unpredictable weather, while differences between fields and within a field are due mainly to soil conditions. Fertilizer N management which is based solely on yield expectation does not take into account or predict the annual variability in growing conditions, and can thus lead to incorrect N application.

Measurement of mineral nitrogen in the soil.

Mineral N in the soil profile of a field at the beginning of the growing season is plant-available and thus has a direct impact on the optimum fertilizer rate. The total amount of mineral N down to 90 cm soil depth at the start of vegetative growth is highly variable and may be less than 10 kg/ha or more than 100 kg/ha. In addition estimates of net N supply expected from soil N mineralisation during the growing period can help to refine the management of the additional N required. Soil mineral N in spring and the amount of N that may become available depend on soil type, previous crop residues, previous use of any organic manures and prevailing weather conditions. Soil mineral N supply can be measured by soil analysis or it can be estimated from these influencing factors.

Methods for estimating or measuring soil mineral N in spring provide a good starting point for decisions on additional N requirements. However, unpredictable weather conditions later in the growth of the crop can affect crop N uptake, and soil N supply to some extent, and need to be taken into account.

Soil sampler: Modern equipment for sampling soil to a depth of 90 cm for mineral nitrogen analysis.

With fertilizer N the total amount should be split into two or more applications and measurements on the growing crop can be used to adjust the later ones.

TOOLS:

Tools available to the farmer for assessing and interpreting the quantity of N available in the soil include:

- laboratories which analyse the N content of deep soil cores and estimate the potential for further mineralisation.
- expert advisors, agronomic consultants and those associated with fertilizer manufacturers and distributors who can advise on the results of the soil analysis.
- services which report soil mineral N levels in soils at standard sampling points on a regular basis during the winter and early growing season.
- agronomic advisors who can assist with the estimation of available soil N from the soil type, cropping history, winter weather, etc.

Plant analysis and split dressings.

Plant analysis methods are based on the principle that the plant itself is the best indicator of the N supply from the soil during the growth period. The N status of the crop can be used as a guide to decide the nitrogen rate for top dressings later in

the growing season. The use of several split applications enables the farmer to optimise the amount and timing of N fertilizer applications. The accuracy possible with these recommendation systems requires the use of fertilizers with immediate N release properties. An alternative is to apply a nitrogen fertiliser containing a nitrification inhibitor, which releases nitrate to the growing crop over an extended period without such a need for split applications.

Judging the nitrogen status of growing crops.

The simplest and oldest method used by all farmers is visual assessment of the colour and vigour of the crop. The 'fertilizer window' method was developed as an easy-to-use improvement. Farmers apply 10-20% less N on a small part of the field compared to the rest of the field. When the plants in this area start to lighten in colour the farmer can conclude that the amount of N available for the crop in the rest of the field will soon become limiting and can then decide on the next fertilizer application. Alternatively the 'double sowing density' window (in which a small area is drilled twice so that the double density of the crop shows symptoms of shortage of nitrogen before the normal crop) is also an efficient method to decide the timing for the first N application in early spring on cereal crops. Nitrogen concentration in plant tissue can be measured in a laboratory or with a tool kit but the method, although precise, is time-consuming and expensive. Alternatively the farmer can check the nitrogen status with simple devices which are sufficiently accurate for use in the field. It is important that the plant sample is representative of the whole crop. N concentration also changes as the crop develops so the growth stage of the crop must be taken into consideration.

The "Jubil method": The 'Jubil' sap test for nitrate was designed by the French agronomic research institute (INRA) in the early 1990s. The test is used by farmers to help estimate nitrogen requirements for their wheat, barley, maize and potatoes.

TOOLS:

Tools available to farmers to assess the nitrogen status of the crop at different growth stages.

- **Testing plant sap in the field.**
  Simple, non-laboratory and semi-quantitative nitrate sap tests enable farmers to assess the actual nitrogen status of the crop and facilitate decisions on N rate/timing directly in the field. The nitrate sap test is often used to decide the right timing of a fertilizer application. If calibrated correctly, it is also possible to draw conclusions about the amount of N required. Especially in potatoes, the petiole sap test is widely accepted.
- **Measuring the greenness of the crop.**
  Latest methods are based on non-destructive optical measurements of the chlorophyll content. Using handheld instruments the greenness can be measured in the field. Nitrogen fertilizer recommendations can be based either on a relative approach, for example, on the ratio of chlorophyll readings in an over-fertilized plot as reference, or as an absolute recommendation scheme, using the actual deviation from a variety-specific desirable value of greenness as standard.
- **Precise management of the variability.**
  Further accuracy is possible using 'precision farming' techniques that estimate crop N status as it varies across the field. Remote sensing techniques based on instruments that are mounted on a tractor (or occasionally a satellite or aircraft) have been developed to measure plant leaf canopy reflectance of different wavelengths of light. This reflectance can indicate the total biomass of the crop as well as the chlorophyll, and thus N, content. Tractor mounted instruments are unaffected by cloud cover and can be linked through suitable software directly to the fertilizer spreader. This offers the prospect of real-time estimation and application of the optimum amount of fertilizer N to every point in the field.

Application of nitrogen fertilizer supplemented with sulphur on rape seed.

Sulphur deficiency is difficult to predict.

Occurrence of sulphur (S) deficiency is affected by amount of S deposited from the atmosphere, soil type and crop species. Anthropogenic emissions of S from industrialised countries in Europe have fallen very significantly in recent years, as illustrated in Figure 6. These reductions have led to the need for sulphur fertilization for the first time in many areas. Deposition of S varies widely across Europe, from less than 4 kg S/ha/year to more than 20 kg S/ha/year. Brassica species and grass cut for silage are particularly prone to S deficiency, especially when grown on light textured soils. Livestock manures contain useful amounts of total S but plant-availability of the nutrient decreases markedly during manure storage. Therefore manures can not be relied on to correct deficiencies. Consequently, various S-containing fertilizer products have been developed to meet crop needs.

Decisions on sulphur application.

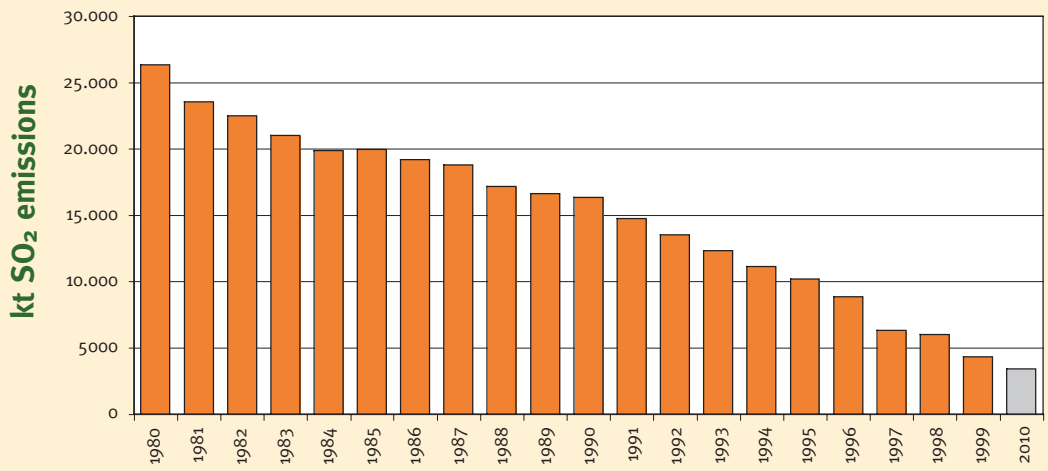
Visual assessment of S deficiency is possible but symptoms are similar to those of N deficiency and erroneous application of additional nitrogen will only aggravate a lack of sulphur. Furthermore, results of visual assessment or plant tissue analysis can be too late for effective remedial action. Soil and plant tissue analysis methods have been developed for determining crop S status, and thus whether there is a need for fertilizer S. Because sulphate-S (SO_4^{2-}) is mobile in the soil, soil sampling to around 90 cm is necessary for a representative result. Plant tissue testing is more common. Sulphur concentration in plant tissue, the N/S ratio and the sulphate/malate ratio have been used to diagnose S deficiency. When sulphur deficiency becomes measurable or even visible, crops have been damaged already and part of the yield potential is lost irretrievably. Limited remedial action is possible through foliar application. Various S deficiency risk assessment methods, taking into account local level of S deposition, soil type and crop species, have been developed to overcome this problem and to offer a predictive estimation.

TOOLS:

- Visual colour assessment.
- Soil sampling to 90 cm as for nitrogen.
- Plant tissue analysis:
  - Nitrogen/sulphur ratio.
  - Sulphate/malate ratio.
- Predictive estimations(ready-reckoners).

Figure 6:

Anthropogenic emissions of sulphur within the EU-15 as kt SO_2 (source: UNECE and EMEP)



3.1.2. Less mobile elements in soil (phosphorus, potassium, magnesium, calcium).

Nutrient reserves in soil.

Some nutrients move very slowly in soils and tend to remain in the crop rooting zone. The main nutrients in this category include phosphorus (P), potassium (K), magnesium (Mg) and calcium (Ca). Crops take up these nutrients primarily from soil reserves and the role of fertilizers or manures is to maintain these reserves at adequate levels. Consequently, these nutrients added in manures or fertilizers may be taken up only to a limited extent by the current crop. Using isotopes, it was found that a maximum of 15% of newly-spread P was taken up by the crop to which it was applied with the rest of the P required being recovered from soil reserves. The majority of the applied P was necessary to replenish the soil reserve and thus to compensate for the P removed in the harvested crop.

Nutrient management planning.

The soil provides reserves of nutrients required by crops. To make a decision on planning, two questions must be answered:

- What is an appropriate level of soil reserve for each nutrient (P, K, Mg)?
- Is an addition of any nutrient necessary to achieve this adequate level for the crop or to maintain this level over time, compensating for removal by successive crops?

In conjunction with regular soil analysis, nutrient mass balance calculations can be used to predict potential changes in soil reserves and to identify probable trends. The nutrient balance is the difference between the addition of a nutrient in manures and fertilizers and the removal of that nutrient in the harvested crop or livestock product; it is usually measured over the period of a rotation. There will be some uncertainty about the amounts of nutrients applied in manures and slurries and in the amounts removed from grazed grassland. Also a nutrient balance will not take into account changes in the availability of a nutrient due to chemical processes in the soil. Soil analysis is therefore used at intervals to check on actual changes in soil nutrient status and to help decide on nutrient management planning. Herbage analyses can also be used to indicate the level of soil reserves in grassland or the removal with the harvest.

Soil sampling by hand.

TOOLS for soil monitoring:

A programme of soil analysis on the farm to test all fields every 3-5 years.

- Soil analysis methods and interpretation have been developed over more than a century, by scientists and governmental advisory services with the active participation of the fertilizer industry, to estimate the reserves of nutrients in the soil available to the plant.
- Because of soil variation within fields, sampling procedure must be appropriate and consistent. Sampled areas must be chosen carefully according to soil types and crop rotations on the farm, and be identified on the farm map. It is easier to identify a trend over the years when sampling in the same representative area located precisely using GPS.

Interpretation and recommendation for each nutrient.

- Interpretation of soil analysis results has been based on crop responses from a large number of field experiments over very many years and takes account of all influencing factors, including regional soil types. Recommendations can be calculated by farmers and advisors based on this wealth of response data. Software used by laboratories or accessed by internet can also be used to facilitate calculations and give recommendations for applying each nutrient according to the crop, the rotation and target yields entered by the farmer on a field-by-field basis.

Calculation of nutrient requirements.

The principle of fertilising for the less mobile nutrients is to maintain the soil nutrient level in a field within a target range depending upon the most responsive crop in the rotation and the soil type. Where analysis shows the soil reserve to be greater than the target level, nutrient applications may be reduced or even omitted until the target value is reached. Where soils are below the target level, nutrient applications should provide more than is removed by the crop to ensure yield response and to build the soil nutrient level gradually to the target.

All sources of nutrients should be taken into account before deciding on the amount of fertilizer needed. These other sources include manures, slurries and any other organic materials applied. Standard estimates are available for the amounts of total and available nutrients in manures and organic materials. Often, where manures are applied, there may be no need for fertilizers. However, it is important that soil reserves of the less mobile nutrients are maintained to preserve soil fertility.

Efficient recovery of fertilizer nutrients.

Individually, the estimated rotational nutrient requirement for P, K or Mg can be targeted on the most responsive crop in the rotation, and subsequently omitted for the following crop(s), although regular annual applications of nutrients to maintain the soil nutrient reserves are preferable to such large multi-season applications.

Although not as important as for N or S, timing of application can improve crop recovery and response, especially for soils with low nutrient reserves. Split-application is sometimes worthwhile, for example with fertigation.

Fertilizer placement for potatoes: Band placement of fertilizer beneath the seed tubers of potatoes at planting to improve nutrient use efficiency.

Localisation of 'starter' P fertilizers near seedlings can provide additional immediately-available nutrient in the early stages of growth when root systems are limited, with benefits for yield or quality and for the earliness of harvest. Band placement of the main dressing of these immobile nutrients P, K and Mg can provide improved crop performance where soil reserves are low and for crops with limited root systems, such as potatoes.

TOOLS for calculating nutrient requirements:

- National recommendations are available for the amounts of nutrients needed for each crop, which take into account measured soil nutrient reserves, soil type and potential yield, on a field-by-field basis. First the nutrients available in manures are estimated and these are used on the farm according to EC and national regulations, for example the Nitrate Directive. Adjustment can then be made for each individual nutrient by applying single mineral fertilizers for P, K or Mg or by using standard and tailor-made products with the appropriate balance of nutrients.

3.1.3. Micronutrients.

Some essential nutrients required in only very small amounts by crops are termed micronutrients and include boron, copper, iron, manganese, molybdenum and zinc. Deficiency of a micronutrient can occur where a soil contains very little of the nutrient (for example, sandy soils) or where soil conditions restrict the availability of the nutrient. Soil pH is important in affecting micronutrient availability and as a result crops growing on calcareous soils with high pH can suffer from an induced deficiency of manganese, copper and boron (see Figure 5, page 14). Molybdenum is an exception; in the case of this element availability tends to increase with increasing soil pH.

Micronutrients are often applied to perennial crops as a foliar spray.

Where soil conditions induce a deficiency, the nutrient should be applied in a protected (chelated) form or directly to the crop foliage so that it can be taken up through the leaves. A wide range of inorganic and chelated forms of soluble micronutrient products has been developed. These may need to be applied every year or to the more sensitive crops within a rotation.

Where the soil contains very little of a micronutrient, the nutrient can be effective when applied to the soil. On sandy soils for example fertilizers may be supplemented with boron to meet crop needs, even though the soil reserves of boron cannot be built up.

Grassland presents special issues because micronutrients are needed by both grass and by grazing livestock. A further complication arises because animals require some micronutrients, such as iodine and selenium, which are not nutrients required by the grass, although they are normally taken up by the grass and so supply the animal. Deficiencies in grassland are generally important from the perspective of the animal but they can usually be corrected by application of the micronutrient to the grass either in supplemented fertilisers or in foliar sprays. However it is often convenient to add the micronutrient directly to the livestock diet in supplemented concentrates, in mineral licks or, during the summer, in drinking water.

TOOLS:

- Experience will often enable a good assessment of the probability of the occurrence of a deficiency, because micronutrient deficiencies tend to be associated with particular soils (i.e. fields) and with specific crops.
- Soil analysis and plant tissue analysis are used to identify micronutrient deficiencies.
- Special soil analytical methods have been developed to assess accurately the availability of micronutrients.
- Special photographic reference books have been produced to assist with the identification of crop micronutrient deficiency symptoms.

3.2. Recycling of manure or other organic wastes.

Nutrients in manures and crop residues produced on-farm must be recycled efficiently back to the soil for use by the next crop; a correct estimation of their nutrient content is thus needed. Appropriate timing and spreading techniques are also necessary to avoid losses and to improve recovery by crops.

Livestock manures and other organic wastes are valuable sources of nutrients that must be taken into account when planning fertilizer applications. Nutrients in manures derive from forage grown on the farm and from imported feeds; it is important they are recycled effectively. This recycling benefits the farmer economically and minimises losses of nutrients to the wider environment. The total and available nutrient contents of manures can be measured or estimated so that the balancing fertilizer requirements can be calculated. In some regions with intensive livestock production, manures (sometimes processed to reduce bulk) are exported to other, mainly arable, areas. This helps ensure the best utilisation of nutrients by avoiding any excessive applications.

Managing manure nitrogen is complicated.

The N in manures is partly in organic forms that are not immediately available to plants. After application, available N is released from these organic forms through mineralisation. This release occurs over an extended period, sometimes several years, and is not predictable with accuracy. Some N will be released at times when uptake by a crop is small or zero (for example during autumn and winter before a spring-sown crop) and is then at risk of loss by leaching. This potential for N loss has to be taken into account when planning manure applications.

Table 4:
Typical nutrient content of animal manures.

Source: Potash Development Association, from data provided in UK MAFF booklet RB209.

	Dry matter %	**Total** nutrients			**Available** nutrients [1]		
		N	P_2O_5	K_2O	N	P_2O_5	K_2O
Fresh FYM [2]		**kg/t**			**kg/t**		
Cattle	25	6.0	3.5	8.0	see Table 5	2.1	7.2
Pig	25	7.0	7.0	5.0		4.2	4.5
Poultry Manures		**kg/t**			**kg/t**		
Layer manure	30	16.0	13.0	9.0	see Table 5	7.8	8.1
Broiler/turkey litter	60	30.0	25.0	18.0		15.0	16.0
Slurries		**kg/m³**			**kg/m³**		
Dairy [3]	6	3.0	1.2	3.5	see Table 5	0.6	3.2
Beef [3]	6	2.3	1.2	2.7		0.6	2.4
Pig [3]	4	4.0	2.0	2.5		1.0	2.3

[1] Nutrients that are available to the next crop.
[2] Nitrogen and potash values will be lower if FYM is stored in the open or for long periods.
[3] Adjust nutrient content if % DM is higher or lower.

Proper storage facilities.

Because crops use nitrogen from manures only at certain times of the year, effective storage of livestock manures is necessary to preserve nutrient value. Manure storage capacity on farm must be calculated according to livestock number, optimal agronomic period for spreading on grass or arable crops, and crop rotation. In some areas, especially in Nitrate Vulnerable Zones, there are legal requirements for minimum storage capacity. In temperate areas of northern Europe the required storage capacity can be up to nine months of production and the period of spreading limited to a few months.

Storage areas for solid manure should have a relatively impermeable base and drainage liquids should be collected into suitable storage. For urine and slurry there is a particular risk of volatilisation of ammonia during storage due to a relatively high pH. To avoid ammonia loss a tight surface or crust should be established on slurry lagoons and slurry tanks can be covered. The risk of ammonia loss can be further reduced by reducing pH of slurry by the addition of sulphuric acid.

Table 5:

Percentage of total nitrogen available to the next crop following applications of animal manures (% of total nitrogen).

Source: Potash Development Association, from data provided in UK MAFF booklet RB209.

Timing	Dry matter %	Autumn (Aug-Oct)		Winter (Nov-Jan)		Spring (Feb-Apr)	Summer use on grassland
Soil type		sandy/ shallow	medium/ heavy	sandy/ shallow	medium/ heavy	all soils	all soils
Surface application							
Fresh FYM	25	5	10	10	15	20	n/a
Layer manure	30	10	20	15	30	35	n/a
Broiler/turkey litter	60	10	20	15	25	30	n/a
Dairy/beef slurries	6	5	15	20	30	35	20
Pig slurry	4	5	20	25	40	50	30
Soil incorporation							
Fresh FYM	25	5	10	15	20	25	n/a
Layer manure	30	10	25	20	40	50	n/a
Broiler/turkey litter	60	10	25	20	40	45	n/a
Dairy/beef slurries	6	5	20	20	35	45	n/a
Pig slurry	4	5	20	20	45	55	n/a

n/a = not applicable.

The nutrient calculation.

The nutrient content of livestock manures at farm level must be calculated annually because it will change with animal age and type, feeding efficiency and types and amounts of imported feeds. Web and PC-based software and tables with national or regional data for the nutrient content of animal manures under different feeding and housing conditions are available. However chemical analysis of manures may be appropriate, even if only to compare the situation on a particular farm with the available set of average data.

Manure management plan.

First the quantity of nutrients in the available manure must be calculated for the number of animals and the type of housing; national or regional references are usually used for this calculation. For example a Danish farm with 50 Holstein Friesian dairy cows kept indoors all year and bedded on straw is calculated to produce a total of about 6,500 kg N in total, using the Danish reference values.

The next step is to establish an integrated manure and fertilization application plan. In the EU there is a general limit of 170 kg N/ha from organic manures in nitrate vulnerable zones (Directive 91/676 EC). Thus for the 6,500 kg N a minimum of 38 ha area is necessary for the spreading of the available manure. Straw-based farmyard manure can be ploughed into the soil before sowing, while slurry is preferably incorporated into the soil but can be top-dressed onto grass and will have a faster nutritional effect on crop.

Of the total N in the manure only a proportion can be estimated to become available for plant uptake in the season of application. This estimation depends on the type of manure, the timing of application and the type of soil (see Table 5). In addition, the total input of phosphate (kg P_2O_5/ha) and potash (kg K_2O/ha) must also be taken into account.

Once the nutrient contribution from manures has been estimated, this can be subtracted from crop requirements to determine the quantity of nutrients, if any, that must be supplied by fertilizers

The Quantofix™ system for estimating the nitrogen content of manures on farm.

Transfers should be recorded.

An arable farmer importing organic manures should know the nutrient content of the manure supplied, i.e. the content of total N, ammonium-N (immediately plant-available N), P_2O_5 and K_2O. In the case of imported organic industrial waste or similar to the farm, a certificate showing concentrations of heavy metals should be standard for an integrated farm system.

Spreading manures.

The even application of the nutrients in solid manures presents a greater challenge to the farmer than spreading manufactured fertilizers, but recently-developed spreaders, when used correctly, can apply reasonably even dressings. Fluid slurry can be more precisely spread using modern equipment, with several techniques being available to suit different situations.

Top-dressing winter wheat with pig slurry using a special trailing pipe applicator supplied via an 'umbilical' pipe from a tanker on the field margin.

Applications to grassland have tended to use less sophisticated machinery, which often has a relatively high potential for loss of N as volatilised ammonia.

Spreading farmyard manure

However recent advances include the sub-surface injection of slurry into grassland and the application in bands to the soil surface using boom spreaders with flexible trailing pipes (both methods usually being carried out by contractors).

TOOLS:

- Measurement or estimation of nutrient contents (using tables, analyses, or a specific tool kit).
- Development of a manure management plan assessing the quantity to be applied per field and for each crop or for grass.
- Minimised heavy tanker traffic on fields by using slurry applicators fed by an umbilical system.
- Addition of a nitrification inhibitor to reduce potential leaching losses as nitrate.

Appropriate handling and utilisation of livestock manure and organic waste resources.

If organic materials are not stored, handled and applied effectively, there is a risk that nutrients contained in them will be lost to the wider environment.

Good farming practice for dealing with livestock manures and other organic materials includes:

- Determination of annual quantity of manure available (livestock, housing, use of litter, etc.).
- Determination of storage capacity needed by regulation and for optimal timing of application.
- Checking for absence of contamination by heavy metals (e.g. copper or zinc).
- Assessment of risk of ammonia volatilisation (in housing, during transfer of manure and storage) and of ways of reducing such loss.
- Estimation of potential mineral N available in the first year and in subsequent years.
- Timing of application, considering the immediate crop uptake potential from liquid manures, or the later mineralisation and availability from solid manures.
- Keeping a record of quantities applied per field.

Boom spreaders, with or without trailing pipes, can also be used in early spring on some winter-sown arable crops, notably cereals. However the majority of manures applied to arable land are spread on the soil and incorporated prior to sowing or planting, especially for potatoes. With care and with good machinery such applications can be made with reasonable accuracy, but precise dressings of evenly applied N are difficult and cannot be relied upon at high application rates.

Technological solutions.

Animal manures are bulky and costly to transport and handle. That is why they are predominantly used within the farm. When manures have to be exported off the farm various methods have been developed to address this problem and to improve the utilisation of nutrients.

- In some areas poultry litter is burned to generate electricity, for example in the UK, with the ash resulting from the incineration being sold as a more concentrated source of P and K for crops.
- Another solution is the separation of slurry into liquid and solid, fibrous fractions. The solid fraction can be burned to exploit its energy (carbon) content and this helps to make the separation process economic. The liquid fraction can be applied to land as a nutrient source.
- Slurry can be separated in large industrial plants but systems which can be used on farms are available. Slurry also can be used in biogas plants to generate methane, again centrally or on the farm. The residues from this process are used as a nutrient source because they still contain all the nutrients.
- Various methods for drying and pelletising manures have been developed. Removing water greatly reduces the bulk of manures and makes transport more economic. Granulated materials also are easier to spread evenly and accurately for a more efficient use of nutrients.

Spreading and application of manure and organic waste.

The following considerations will in general reduce the risk for nutrient loss and improve nutrient availability for plants:

- Injection or surface band application for liquid manures, rather than the use of 'splash-plate' spreaders.
- Incorporation of solid manures into the soil.
- Control of the evenness of spreading through improved maintenance and calibration of spreading machinery.

An on-farm bio-gas plant in Austria for the generation of electricity, with the effluent being used as an organic manure on the farm.

3.3. Integrated nutrient and farm management.

The principles of crop nutrition and the availability of tested farming methods, tools and technologies have been identified in earlier sections. When the sum of this knowledge and expertise is used in combination with local farming experience, the result is the co-ordinated management of the whole farming system, providing a sustainable basis for farming and for the environment. This management of the complex combination of variables involved is well described by the term integrated farm management, a dynamic and progressive approach adopted by many leading farmers across Europe.

Nutrients have a high profile within integrated farm management because there are many external influences which impact on the efficient use of both manures and fertilizers; these are mainly associated with the unpredictability of the weather and the diversity of the local environment. Typically therefore integrated nutrient decision-making is relatively management intensive.

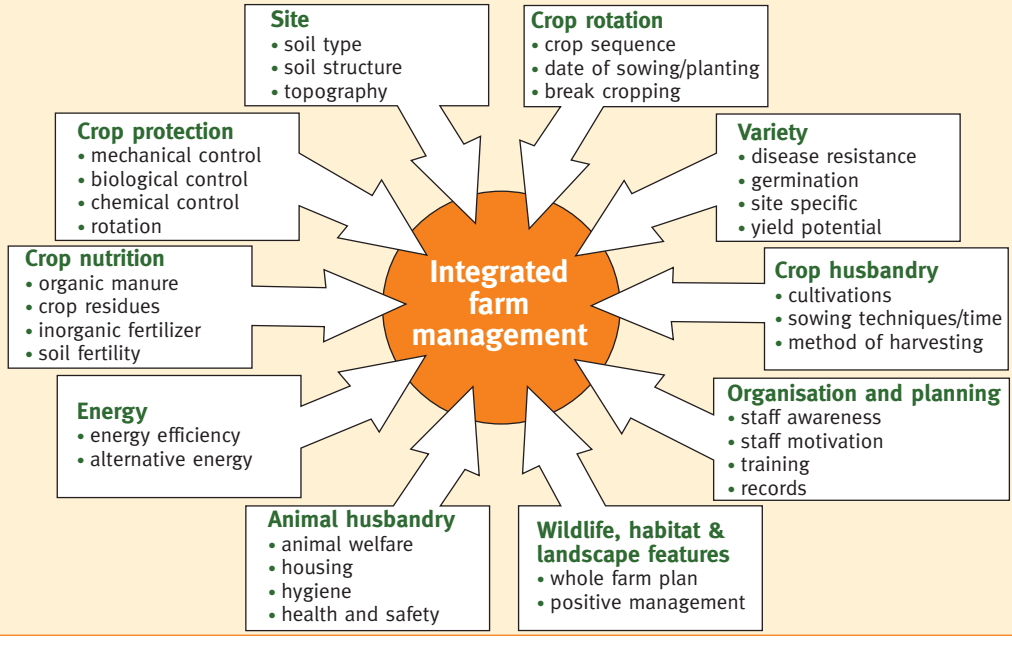
Its success depends upon the quality of local and regional knowledge and experience of all practitioners involved – those based on the farm and also from those in supporting roles. The key feature of this process is that it integrates past experience and new knowledge into decision-making for varying situations – a continuous and dynamic approach resulting in management decisions that are correct for any particular time and circumstance. It is the opposite of a static blue-print.

The nutrient management philosophy is based on:

- Site- and situation-specific knowledge.
- Organisation and planning.
- Re-evaluation of plans against prevailing influences.
- Application of best practice for each unique set of conditions.
- Recording of actual decisions made, from which lessons are later learnt.

Integrated farm management - an overview.

"Balancing economic production with environmental responsibility".



Site- and situation-specific knowledge.

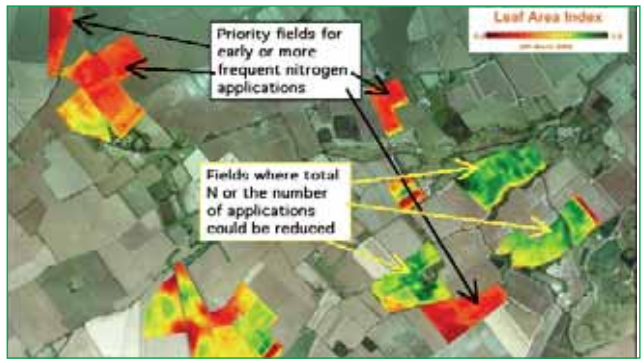
The principle of the integrated approach begins with an understanding of the characteristics of the soil and the pattern of variability at farm and field level, and the topography of the land.

The soil and its condition determines plant development and nutrient uptake, and combined with topography creates the potential for nutrient movement either down the soil profile or across the land surface.

Thus soil and nutrient management may need to be adjusted to accommodate the variability that exists, specifically in areas:

- of nutrient deficiency or excess as determined by soil analysis,
- where application may be inappropriate at certain times, e.g. because the area is prone to water-logging or run off,
- which are sensitive to application of additional nutrient such as hedgerows, areas of biodiversity and watercourses.

Integrated nutrient management means that the nutrient needs of the growing crop are intrinsically linked to the need to protect soil, water and air quality and to maintain and encourage biodiversity. The practising farmer will not only be able to identify any negative effect of elevated nutrient concentrations in the natural farming environment but also the potential source, such as from a slurry store or spreading activity, and the pathway by which that nutrient might reach a sensitive area.



An aerial photograph overlaid with images of certain fields showing remotely captured information on the spatially variable leaf area index of the wheat crops in the fields. Using this information, more precise decisions on nitrogen fertiliser applications can be made.

TOOLS:

- Soil maps showing the different soil types on the farm.
- Maps showing areas with potential for soil or water movement down slopes.
- Maps detailing areas of biodiversity and other environmentally sensitive areas.
- Maps with watercourses clearly marked.

Organisation, planning, practice and re-evaluation.

Not only mineral fertilizers, but also all types of livestock manure or other organic manures applied to land are accounted for in an integrated policy. The land available for manure spreading is calculated in relation to the amount of the organic resource available and its nutrient content. As a first priority, a check is made to ensure that the available manure does not exceed the capability of the land area to receive it, nor breach any regulatory limits that have been introduced at field-by-field or farm level. Also, unnecessarily high levels of N and P in bought-in feedstuffs are avoided.

Organic manure and slurry storage facilities are correctly designed at the planning phase, in terms of position and capacity, and consideration given to the export of organic materials from the farm if quantities would exceed good application practice.

Integrated nutrient practice on a field scale ensures that the farmer knows:

- how much manure is applied, at what time of year and to which field,
- what is the nutrient content of the manure, and
- that it is applied as evenly as possible using the most appropriate machinery and technique.

Regular soil tests for soil pH, and for soil reserves of phosphorus, potassium and magnesium allow the use of these nutrients to be matched/targeted to the needs of the soil and the crop being grown. The farmer aims to maintain the soil nutrient status at a level to give optimum yield and to protect the environment. Fertilizer rates are adjusted to balance the nutrients removed in the crop at harvest, first accounting for contributions of available nutrients from organic manures. The correct integration of organic nutrients and additional fertilizer is an important factor in relation to phosphate in the context of potential negative impact on water ecology. It is also acknowledged that fertilisation in which the supply and availability of all nutrients and lime is matched to the needs of the crop is important for environmental protection, in that this promotes the efficient use of phosphate, and nitrogen. Applications are timed for optimum efficiency of uptake and spread using machines that have been set up to apply the fertilizer evenly. Techniques for variable application may be used where fields are large and have varying soil types.

GPS spreading with Sensor: Tractor fitted with a GPS receiver and a sensor which indicates the N-content of the crop and which thus allows adjustment of the fertilizer application rate.

Along with other aspects of modern agriculture, nutrient management is becoming increasingly technical and research-based. As a matter of principle, advantage is taken of available external advice and information, sometimes requiring advice from a suitably qualified person, although the farmer may also choose to acquire extra qualifications that allow him to select products and strategies that achieve the best results on his own farm.

TOOLS:

- Organic manure management plan (including how to deal with a surplus if applicable).
- Published tables and references for assessing the nutrient content of manures.
- Sampling and analysis kits and laboratory facilities.
- Guidance on regulations etc.
- Nutrient Management Plans by crop type.
- Advice and technical recommendations – from a recognised professional adviser or establishment, or from reliable published materials.

Nitrogen application is most critical for economic and environmental performance. Integrated nitrogen management helps farmers to meet legislation implemented by the EU Nitrate Directive, where it applies in Member States. Phosphate management in relation to the ecological status of water is becoming an issue and is now being addressed within the EU Water Framework Directive. The techniques employed at farm level to mitigate any effects may be different to measures which are effective for nitrogen management.

Field visit with farmers

Possible crop nutrient deficiencies are identified using local knowledge to assess the risk to crop performance and nutrient uptake efficiency before the symptoms appear. In addition, application machinery is calibrated for each product being used and tractor drivers are fully aware of the implications of poor spreading practice, particularly in sensitive areas.

Training of farmer and operators

Best practice, by definition, means that farmers are trained to recognise the conditions necessary for efficient nutrient use. They will also be aware of the consequences of poor product and machinery quality and will be prepared to make use of external advice if necessary to achieve desired outcomes.

Fertilizer storage practice also falls within the scope of integrated farming obligations, ensuring that each storage site is in a safe location for environmental protection and for fertilizer security and safety. Day-to-day management of the stores meets National Guidelines and good house-keeping standards.

Good fertilization practices: Soil management

Part 1:	**General considerations**
1.1	Soil mapping, including farm map of soil types and areas at environmental risk.
1.2	Long term crop rotation plan, with 3-year forward planning.
1.3	Up-to-date advice and technical recommendations for soil management.
1.4	Organic matter management policy, including crop residues and manures.
Part 2:	**Decision making process**
2.1	Soil management plan is required, to help with cultivation decisions.
2.2	Monitoring soil quality through regular soil analysis.
2.3	Soil examination and identification of any areas at risk of erosion.
2.4	Assessment of soil conditions in the field prior to cultivations.
Part 3:	**Implementation of measures on farm**
3.1	Record of soil operations, by crop type and by field.
3.2	Soil cover Index, for protection of the soil surface during winter
3.3	Choice of appropriate soil operations to ensure and improve structure and microbial activity.
Part 4:	**Evaluation of measures**
4.1	Evaluation of the Soil Management Plan by regular review.
4.2	Recommendations to take forward, based on analysis of the previous year's plan.

Good fertilization practices: Crop nutrition

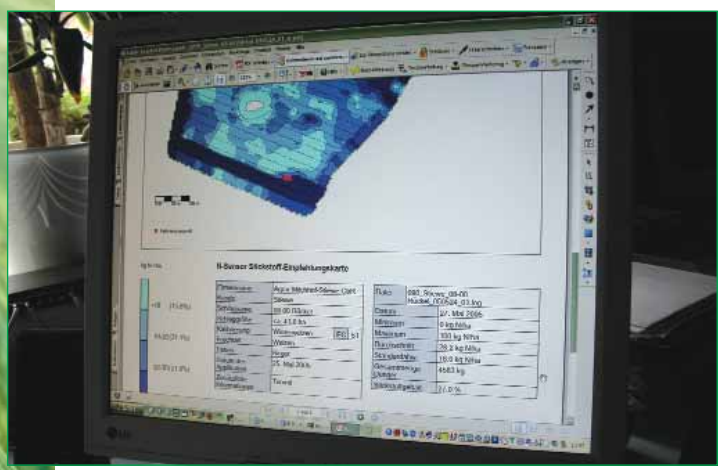
Part 1:	**General considerations**
1.1	Crop Nutrient Management Plans for all crops and for nutrients from all sources.
1.2	Management plans for all livestock manures and other organic sources.
1.3	Training for manure and fertilizer spreader operators.
1.4	Advice and technical recommendations must be kept up-to-date.
Part 2:	**Decision making process**
2.1	Calculation of nitrogen needs to limit potential leaching losses.
2.2	Nitrogen use efficiency estimated by comparing inputs with harvested offtake.
2.3	Phosphate and potassium balance in the rotation assessed from all inputs and crop offtakes.
2.4	Secondary and micro-nutrient deficiency potential identified.
Part 3:	**Implementation of measures on farm**
3.1	Records of all nutrient applications kept for each field.
3.2	Storage of manures and other organic based fertilizers appropriate and within guidelines.
3.3	Safe storage of mineral fertilizers and with care to preserve quality.
3.4	Records of import/export of organic materials handled on the farm.
3.5	Maintenance and calibration of manure and fertilizer spreading equipment.
Part 4:	**Evaluation of measures**
4.1	Evaluation of results to check for effective decision-making.
4.2	Recommendations for following years based on analysis of previous performance.

TOOLS:

- Calculation of nitrogen needs and fertilization performance - sensors for monitoring and precision technologies (for field mapping) may be beneficial in certain situations.
- Phosphate and potash balance – using published tables and calculations.
- Precision technologies (for field mapping in certain situations).
- Special slow release and nitrification-inhibited fertilizers are available for specific uses.
- Secondary and micronutrient deficiencies identified by a risk assessment process, including soil and leaf analysis methods as appropriate.
- Operator training for spreading, including spreader/ sprayer maintenance and calibration, calibration guides and test kits.
- Maps showing fertilizer stores, itineraries of stocks, regular inspections and personnel training to keep ahead of standard practice and relevant legislation, and in the use of the available tools.

Recording and evaluation.

Integrated farm management puts emphasis on recording and monitoring and learning from the evidence provided by field and farm records. Records of nutrient application and subsequent yields achieved will enable a balance to be drawn up and allow adjustment of future nutrient management policy based on fact. In this way farmers aim to preserve soils, protect the environment and the integrity of their business.



By auditing nutrient management practices as a part of an overall annual farm audit, the results are evaluated in the context of all farming activities – allowing the farmer to assess the farm's performance against neighbours and peers, and other performance indicators, e.g. science or survey datasets. This process identifies weaknesses as well as strengths in the farming business and helps target outstanding issues by building them into future planning.

It is the continuing assessment of all aspects of the farm and its environment, and the follow-up response to ensure continuing improvement which differentiate this dynamic integrated approach from standard or even specialist farm management practices.

TOOLS:

- Records of all nutrient applications.
- Evaluation of result;
  - by a farm audit or similar tool for self-assessment
  - by summaries of scientific or data reviews.

Figure 8:

An illustration of the dynamic year-on-year progress of an integrated farming approach, using improvement opportunities identified by the appraisal and auditing of annual performance.

4. Crop nutrition in river basin management.

Overall, environmental sensitivity varies geographically according to the pressures of land use, geological characteristics, and the relative value placed on environmental quality – such as clean water, recreational requirements, biodiversity and clean air. Within any geographic area the relative urban and rural pressures will need to be evaluated before agreeing on the benefits of actions to protect desired environmental goods. An integrated management approach such as that described in Section 3.3 can provide the framework necessary for successful nutrient management under the Water Framework Directive.

Management of environmentally sensitive areas.

From 2009, the scale and means by which multi-functional land use issues will be addressed by EU Member States will be largely determined by the implementation of the EU Water Framework Directive, which as described will provide a framework for managing anthropogenic effects on the environment based on the characterisation of water bodies.

Clearly, water quality is the main focus of this Directive but a fully integrated approach will also have to give due attention to soil and air interactions and the risk of counter-effects. The management unit will be the River Basin within which catchment-based activities will be co-ordinated. River Basin Management Plans will be drawn-up, based on understanding of the processes in catchments, implemented and reviewed on a six year management cycle.

Significance for farmed land.

In respect of the nitrogen and phosphorus in farmed soils, farm management can potentially be influenced by this Directive, depending upon the environmental priorities that are determined within a catchment and the level to which farm derived nutrient sources are associated with the chemical and ecological status of water. Other crop nutrients will only be implicated by the Directive in so far as their balanced use is essential for the efficiency of nitrogen and phosphate management; a deficiency of one key nutrient being a limiting factor to the efficient use of all others.

A risk based approach using the philosophy and tools of integrated nutrient management.

In arable areas not receiving applications of organic manures, where nutrient removal in the harvested crop is matched as far as technically possible with

nutrient supply, the nutrient cycle within a field can be fairly precisely managed using the essential tools and principles of integrated nutrient management.

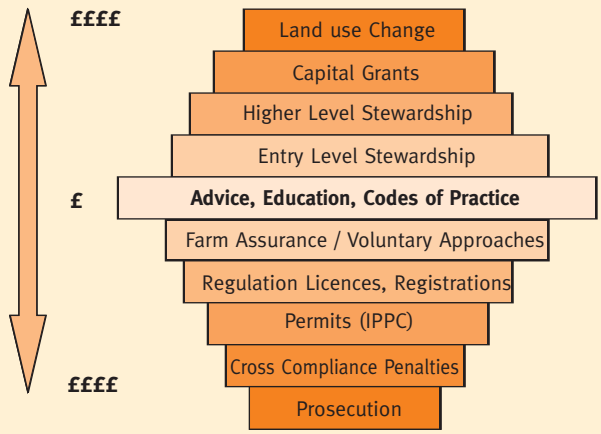
In this farming scenario, the risk of nutrient transfer to water is likely to be low. However, because the integrated farm manager is accustomed to full evaluation of all practices against an annual audit, this discipline in itself will identify those areas or special features of the farm that may require additional attention to detail and will highlight where modifications to general practice need to be made.

Drainage ditch protected by a buffer strip.

For example, where a drainage pathway or lake lies at the bottom of a slope the maintenance or enhancement of its aquatic biodiversity can be targeted by several means. Measures might range from the no cost options, to the low, medium or high, depending on the status of the receiving water and the objectives. A low cost approach would, for example, include the use of contour cultivations and an uncultivated field margin. The medium cost option could involve the introduction of a reed/sediment bed or switching the cropping pattern from a high risk crop (e.g. potatoes) in a high risk situation, to a low risk crop (e.g. winter wheat) in a high risk area.

A high cost option, in farming terms and therefore the last resort, might include the conversion of land from arable cropping to grassland with the resultant loss of farm productivity and income to be considered. In most cases the process of integrated nutrient management will identify the low cost options first to address the problem and so reduce the probability of having to resort to extreme measures, which could threaten a sustainable farming business and food production.

Figure 9:
The 'tool kit' for change showing contrasting options.



In Figure 9 the 'Tool kit for change' illustrates the least-cost options for managing issues at the centre of the chart, with higher costs associated with divergence from this central integrated farming approach. The highest costs are associated with change of land use on the one hand, and the introduction of a legal framework, including prosecution and taxation on the other.

Livestock manures.

In areas where livestock manures are applied to land as part of grassland management there can be an additional risk to water quality associated with the less predictable nature of organic manures compared to inorganic nutrient sources. In addition organic manures present the greater challenges of accurate prediction of nutrient availability and achievement of an even spread. The discipline of integrated nutrient management will limit the risk to water as far as practically possible but for some farms, depending on their site and situation, more detailed farm auditing will reveal whether the land available has the capacity to receive the manures that are produced there.

Calculating the balance.

Mass balance calculations, including the nutrients imported to the farm in animal feeds, can be useful in establishing whether the farm unit is at risk of producing organic manures surplus to requirements. A field-by-field, fully integrated assessment of soil nutrient status and crop/grass needs will give the detailed picture. Based on this information the Integrated farmer is in a position to consider stocking rate policy, grass and feed management decisions and the possibilities of exporting manures to farms with greater land capacity, in order to meet the requirements of any approaching environmental issues.

Managed environmental protection.

Simple, relatively inexpensive changes to the way that the livestock farm is managed can have subtle but significant effects on environmental protection. These can include fencing off vulnerable river banks and moving feeders and troughs to reduce poaching damage, and also the relocation of gateways to a lower risk area. The export of manures to neighbouring farms or to local composting or incineration plants and the provision of permanent livestock access paths are all options which will be raised in an integrated farming pack of tools and guidance. If more major measures are deemed necessary due to particular water quality issues in the catchment/river basins associated with identifiable agricultural areas, more expensive options might have to be introduced. These could include options such as reducing stocking numbers to achieve an acceptable nitrogen, phosphate surplus for the farm, or expansion of or new storage facilities, but it is clear that these costs would require external financial support in terms of incentives or compensation. This is a matter for national governments to manage independently or in combination with EU support, with the agreed policy being integrated into the nutrient management planning and farming system.

Dynamic approach identifies risks and solutions.

The unique forward thinking dynamic approach of integrating farming puts the farmer in control.

Fences ensure that livestock do not have access to watercourses and thus cannot contaminate the water directly, nor cause erosion to river banks.

The fact that his whole approach is geared to anticipative management reduces the likelihood of environmentally sensitive issues arising and thus the major costs associated with managing them – therefore saving future costs to the farm and the environment.

There is no doubt that the controlled management of plant nutrients in environmentally sensitive situations is challenging. However the scientific and technical knowledge, the support now available, and his management attitude and expertise enable the integrated farm manager to rise to this challenge.

The understanding and resources identified in earlier sections in this publication provide the farmer with the tools he requires to ensure good practice in the management of organic manures and manufactured fertilizers. An integrated farm management commitment further ensures that this good practice is dynamic and is continually improving.

5. Conclusions.

- Sustainable economic viability for the farmer is essential, for from this viability flows protection of the environment.

- Soil fertility has always been the key to sustainable agriculture, historically and today. Farmers spend much effort, time and investment to improve and maintain soil fertility: appropriate land use, crop rotation, liming, manuring and fertilizing.

- Organic manures and composts contribute valuably to a base dressing of plant nutrients, but generally an additional precise application of mineral fertilizers is required, specifically calculated for each nutrient N, P_2O_5, K_2O, Mg, Ca, S, etc.

- Good management of organic manures is complex. High efficiency of recovery and use of the nutrients in organic manures is difficult but not impossible.

- There is a need to register and classify information for farm decision-making into
  - Field scale (fertilizer adjustment to crop need), and
  - Farm scale (land use, crop rotation), and
  - River basin scale (farming system and policy).

- Adaptation to soil and climatic variability will always require a site-specific approach from the farmer and require his experience as well as his knowledge. Agronomists can help but cannot replace this experience.

- Integrated farm management is dynamic and progressive. The decision-making process includes recording for each crop and non-crop area and in each season, evaluation and training to learn from on-farm and peer group experience and from the latest research and techniques.

- The fertilizer industry has contributed for more than a century to the development of tools to assist the farmer and his advisors, from soil analysis to the latest developments in remote-sensing systems to measure plant needs and condition.

6. Farm profiles and case studies.

So far this book has examined the principles behind good agricultural practice in the context of crop nutrition. It has identified the opportunities for farmers to adopt an integrated approach to the use of both manufactured fertilizers and farm manures, with the objective of maximising the efficient recovery of nutrients from all sources and maintaining the nutritional fertility of the soil. This efficient utilisation of appropriately applied nutrients helps to produce good yields of high quality - necessary for the economic viability of agriculture - and at the same time minimises environmental impact from their use.

The second part of the book looks at some individual farms of different types and from different parts of Europe which are successfully using or preparing to adopt these principles of integrated farm management. These farmers are not exceptional, but are illustrative of the way that farmers themselves see the need to adopt a system of continuous improvement in all aspects of their business. These farmers all have a clear vision of how they can improve the management of the fertilisation of their crops while also improving the natural and varied ecosystems on their farms.

The key to the continuation of these improvements lies in the ability and desire to measure their performance, to use audits where available, and to seek each year to make progress. These case studies show how farmers themselves, with help from their advisors and suppliers, can develop the framework required to deliver an economically sustainable and environmentally better agriculture for Europe.

Hutzingerbauer Farm

AUSTRIA

About the farm:

The farm is located near Salzburg, 800 m above sea level; the average precipitation is about 1400 mm.

Roman Traintinger and his wife Elisabeth run a dairy farm. They have three sons aged between 14 and 20.

Size of the farm:

- 30 ha grassland, 6 ha leasehold grassland;
- 5 ha silage maize;
- 3.5 ha forest.

Livestock density:

- 60 dairy cows (Holstein) with calves and young stock;
- average milk yield 9700 kg per cow.

Storage capacity for liquid manure: 950 m^3.

Equipment:

- limited outdoor machinery for the grassland but;
- a new cowhouse with a modern milking parlour.

Key machinery:

- 2 Tractors of 80 and 100 kW;
- feeder for handling and mixing maize and grass silage.

Austria country facts:

- Total agricultural output of 5.8 billion Euros, which represents 1.2% of country GDP, and 1.8% of total EU agricultural production.
- 170,000 holdings employ 174,000 people which represents 5.0% of total working population.
- Average farm size is 19.0 ha, with 8 cows on average on dairy farms.
- 3.25 Mio ha of agricultural land (38.8% of national territory), of which 38.8% is arable land and 44.6% grassland.
- 0.82 Mio ha of cereals, which represents 1.6% of total EU cereal area, and 0.15 Mio ha of oil and protein crops.
- 0.18 Mt of mineral nutrients in 2004/2005, corresponding to an average application of 34 kg nitrogen, 13 kg phosphate and 16 kg potash per hectare of agricultural land.

Sources : EU Commission, Eurostat, 2003 and 2004. EFMA 2004/2005.

Farming system:

Roman's father was a progressive farmer and used soil analysis and mineral fertilizer. Until 2000 Roman was involved in the Austrian environmental programme (ÖPUL) and produced milk for cheese without feeding silage.

However in 2001 he changed the production pattern drastically from using the regional Fleckvieh breed

and extensive hay to an integrated intensive milk production system using Holsteins and silage. He also produced silage maize for the first time and was in fact the first farmer in the region to grow the crop. However in 2001 the maize hardly reached maturity, with snow already starting during harvesting on 3rd of November. They are now more careful with the maize variety and its maturity number.

Grassland is managed intensively with 5 cuts.

The Traintingers have changed their production pattern in a technically more controllable system and one with better economic sustainability.

Milk yield jumped from 6,500 up to over 8,000 kg in the first year and now, four years later, they are aiming for 10,000 kg. Of course their target is to produce as much of the milk as possible from their basic on-farm fodder.

The feed consists of 40 kg grass and maize silage and 9 kg concentrated feed (barley and soya cake, which will partly be substituted by rapeseed cake) and 1/2 kg straw for rumen health.

The Traintingers take great pride in achieving high quality silage, without any losses and with the highest levels of digestibility and energy density.

Crop nutrition:

Roman's father always paid a lot attention to the maintenance of soil fertility, using a precise fertilization programme. Regular soil testing is used every 5 years to monitor soil nutrient reserves of P, K, Mg and soil pH. Soil analysis shows a typical pattern for dairy farms, with some areas having high nutrient levels but others with low phosphorus status. They believe it important to keep their grassland in very good condition and to maintain soil fertility, with P and K levels appropriate for good productivity.

For silage maize, today they use 45 m^3 of slurry, containing about 100 kg N and they spread an additional application of mineral calcium ammonium nitrate giving 54 kg N.

Plans for progress and improvement:

In the near future they need additional grassland to use the manure on their own farm or their neighbours'. With the stricter nitrate action plan, Roman has to reduce livestock number and so provides calves for his neighbour who breeds them. He is also considering the possibility of participating in the manure stock exchange in his region.

Roman would like to reduce the quantity of slurry applied to not more than 30 m^3 to better balance the nutrients applied to the soil fertility and plant requirements.

Lindelund Farm

DENMARK

Lars Kreutzfeldt and his wife Kirsten with their children on Lindelund farm.

About the farm:

The farm is situated in the Eastern Jutland close to the town of Odder and specialises in pig production.

Size of the farm:

375 ha of owned land with another 80 ha rented.

- Oilseed rape;
- Winter wheat;
- Winter and spring barley;
- Ryegrass.

Pig production in 2005:

- 800 mother sows;
- 3,000 piglets sold;
- 16,000 pigs fattened for slaughter.

Storage capacity for slurry:

- More than one year's production.

Workforce:

- Lars and 8 employees.

Farming system:

Lars has considerably expanded both the land area and the pig production over the past 10 years by buying three neighbouring farms. The purpose of buying these farms has been to ensure an up-to-date and efficient production system. Lindelund Farm is well laid out, with the farthest field being only 4.5 km away.

The main crops include:

- Winter wheat
- Winter barley
- Spring barley
- Winter oilseed rape
- Festuca and ryegrass swards

Denmark country facts:

- Total agricultural output of 8.6 billion Euros, which represents 1.7% of country GDP, and 2.6% of total EU agricultural production.
- 49,000 holdings employ 66,000 people which represents 3.3% of total working population.
- Average farm size is 55.0 ha, with 75 cows on average on dairy farms.
- 2.66 Mio ha of agricultural land (61.7% of national territory), of which 86.8% is arable land and 8.3% grassland.
- 1.49 Mio ha of cereals, which represents 2.8% of total EU cereal area, and 0.15 Mio ha of oil and protein crops.
- 0.31 Mt of mineral nutrients in 2004/2005, corresponding to an average application of 78 kg nitrogen, 12 kg phosphate and 30 kg potash per hectare of agricultural land.

Sources : EU Commission, Eurostat, 2003 and 2004. EFMA 2004/2005.

The soil is heavy with a clay content of approximately 20%. It is well drained and has a high yield potential, with winter wheat yields averaging 8.5 t/ha.

Lars uses his own cereal as grain for the pigs. Spring barley is grown for malt production.

Pig slurry management:

In Denmark there are strict regulations for manure utilisation. All the nutrients from the pig production have to be included in the fertiliser calculations. Standards are set for animals which are housed for the entire year. For example a mother sow with 24.6 piglets per year weighing 7.2 kg each produces 24 kg N, 14.4 kg P_2O_5 and 11.6 kg K_2O a year, according to the standard. The Environmental Regulation III came into force in 2004 with an increased challenge to use the nutrients in the slurry more efficiently. Lars has an adequate area for spreading all the slurry on the farm. The pig manure is spread with band spreading equipment using a 24 metre wide boom or it is injected into the soil. All crops are fertilised with slurry at the beginning of spring at a normal application rate of 20-30 t/ha.
It is difficult to eliminate the smell entirely during the 2-3 weeks it takes to spread the slurry in the spring. “But we never spread manure during the weekend and we try to consider the neighbours by spreading on areas where the wind direction is away from residential areas” says Lars.

Crop nutrition:

For winter cereals the best nutrient utilisation is achieved with relatively early application, when the soil is moist, the temperature still low and the air is humid. Lars keeps an eye on the many Danish trials

with winter wheat which show that good efficiency is achieved by spreading between April 1st and May 10th. Lars stresses that it is important to pay attention to the following practical issues when applying slurry:

- Use only well stirred slurry;
- Avoid spreading on very wet or very dry soil;
- Spread in the morning under a thick cover of crop;
- Estimate the nitrogen content in the slurry using an Agro measuring tool.

Today, reduction of ammonia emission from slurry application is an important issue in Denmark, partly because of the smell, but also in order to optimise efficient use by the crop and soil. On winter wheat, an initial application of ammonium nitrate with sulphur in mid-March supplying around 65 kg mineral N/ha is followed by only one slurry application in April providing the equivalent of 105 kg N/ha. In Denmark it is only permitted to apply 90% of the estimated optimal fertilizer N rate. It is thus now almost impossible to obtain more than 11% protein in the wheat. There is an increased need to supplement the feed for the pigs with extra protein from soya cake.

Plans for progress and improvement:

Lars and Kirsten believe in the future of farming at Lindelund. “But my job has changed gradually as the farm size has increased”, Lars admits. Today Lars is more managing and guiding than working in the fields and buildings. "The purpose is to have efficient production of high quality food products, using the best available technology and with low environmental impact, while at the same time achieving a satisfactory standard of living".

Sutela Farm

FINLAND

The farm is run by Heikki Sutela and his wife. All three children help on the farm, although the two younger ones still go to school. The eldest son is training to be a farmer.

Finland country facts:

- Total agricultural output of 4.2 billion Euros, which represents 1.0% of country GDP, and 1.3% of total EU agricultural production.
- 75,000 holdings employ 103,000 people which represents 5.0% of total working population.
- Average farm size is 30.0 ha, with 18 cows on average on dairy farms.
- 2.25 Mio ha of agricultural land (6.7% of national territory), of which 60.9% is arable land and 28.4% grassland.
- 1.13 Mio ha of cereals, which represents 2.2% of total EU cereal area, and 0.07 Mio ha of oil and protein crops.
- 0.27 Mt of mineral nutrients in 2004/2005, corresponding to an average application of 78 kg nitrogen, 20 kg phosphate and 33 kg potash per hectare of agricultural land.

Sources : EU Commission, Eurostat, 2003 and 2004. EFMA 2004/2005.

About the farm:

The Sutela farm is situated in northern Finland, close to Oulu region near the west coast. The growing season lasts only 140-150 days from May to October.

Size of the farm:

- 40 ha of spring cereal production;
- 54 ha of grassland.

Main crops:

- Silage grass, oats, barley and potatoes;
- Average yield of barley is about 4 t/ha, sometimes up to 5 tonnes.

Soils:

- Light sandy soils, constantly in arable production;
- Organic soils, in grassland.

Cattle:

- 55 milking cows;
- 80 young animals, bulls and heifers;
- 9,400 kg milk per year per milking cow.

Farming system:

The grassland is grown mainly for silage, 47 ha, and for dry hay, 7 ha. The silage grass is fertilised and cut once or twice yearly depending on the yield level. The aim is to cut the silage grass when the following quality criteria can be met: protein content 16-17%, dry matter 40%. When good quality is achieved, the silage has a high palatability and the animals eat and milk well.

There is a combine harvester and a drier on the farm. The aim is to harvest the cereals when the moisture content is about 18% and dry down to 15-16%. Heikki believes it is crucial to have the machinery on the farm to ensure that farm activities can be carried out on time.

The feed for the cattle is based on good quality silage, home-grown cereals, commercial feed mix and minerals. The milk is sold to Valio cooperative, Pohjolan Maito. The cowshed was built some 15 years ago, and the animals have their own stalls. The cows are fed inside the year round, going outside only for exercise during the summer. The liquid manure is stored outside the shed in two big open tanks, with the size of the tanks being sufficient for the storage needs for the whole year. In Finland it is forbidden to spread manure onto frozen soil.

Manure management:

The cattle produce about 2,500 m^3 of liquid manure per year. The manure is spread partly on the cereal fields and partly onto grassland. The profitability of the farm is important and Heikki Sutela wants to maximise the utilisation of nutrients in manure. The aim is to decrease as far as possible the need for extra bought-in fertilizers.

Crop nutrition:

For cereals liquid manure is spread in the spring before sowing. The amount of manure applied is about 25 t/ha with 3.3 kg N per tonne of which only 1.9 kg is available directly to the crop. The nitrogen available from manure is deducted from the total N requirement. For example, the barley crop needs about 90 kg N/ha of which 48 kg is provided by the manure with the remaining 42 kg N coming from mineral fertiliser. Fertilisers are placed between the seed rows some 3 cm below the surface for maximum efficiency.

Soil analysis shows that the organic soils used for grass production have good reserves of phosphorus. Manure is spread onto the grass after the first cut, and with the new machinery the evenness of spreading has improved significantly.

Two different analyses of NK fertilisers are used, which take into account the varying K reserves in the soils.

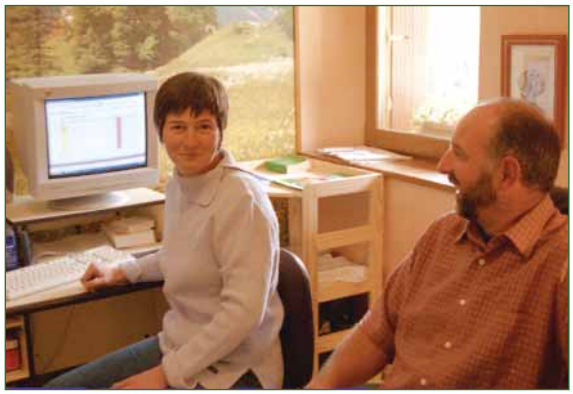
Plans for progress and improvement:

The farm makes good use of the available advisory services and monitors and reports its milk production on a regular basis. The advisor calculates the fertilisation plan for the farm.

In the future Heikki Sutela's son will carry on farming and so there is interest in buying some more land nearby.

Somme Tourbe in Champagne

FRANCE



Benoit Collard manages a 155 ha farm, which he took over from his father in 1983. He has been working with his wife Isabelle on this family farm in the chalky Champagne, 200 km north-east of Paris, ever since.

France country facts:

- Total agricultural output of 64.8 billion Euros, which represents 1.9% of country GDP, and 19.6% of total EU agricultural production.
- 614,000 holdings employ 959,000 people which represents 4.0% of total working population.
- Average farm size is 45.0 ha, with 36 cows on average on dairy farms.
- 29.63 Mio ha of agricultural land (54.0% of national territory), of which 47.9% is arable land and 42.3% grassland.
- 9.33 Mio ha of cereals, which represents 17.8% of total EU cereal area, and 2.27 Mio ha of oil and protein crops.
- 3.89 Mt of mineral nutrients in 2004/2005, corresponding to an average application of 81 kg nitrogen, 26 kg phosphate and 34 kg potash per hectare of agricultural land.

Sources : EU Commission, Eurostat, 2003 and 2004. EFMA 2004/2005.

About the farm:

The arable land is cropped with cereals, sugar beet, potatoes, and also peas, lucerne and rapeseed for biodiesel production. It was decided to diversify in 1989, setting up a poultry unit under a regional quality scheme (red label).

Size of the farm:

155 ha of chalky soil.

Crops:

- 49 ha cereals;
- 23 ha sugar beet;
- 15 ha potatoes;
- 20 ha peas;
- 19 ha lucerne;
- 8 ha rapeseed;
- 21 ha other crops.

Livestock:

- 9,000 head of poultry.

Farming system:

The Collards were among the very first farmers in France to qualify, in early 2004, for the ***"Agriculture Raisonnée"*** a national programme initiated by the government to develop integrated farming as a whole-farm approach. Benoit, a member of the FARRE association, has also invested time in preserving biodiversity and bird life in this intensively cropped region, and works in conjunction with LPO (Bird Protection Association) to preserve habitats along the small Tourbe valley. He has received many visits from those interested in IFM.

A poultry unit, with guinea fowl or chickens, helps diversify the farm revenue and provides manure. Contracts with various agro-industries active in the region and the production of seed potatoes and grass

Benoit Collard examines carefully the soil.

seeds has allowed him to diversify crop rotations. About 10% of the arable land is cropped with energy crops (rape seed on set-aside and sugar beet for bioethanol). This share is likely to increase, to supply new local plants under construction for biodiesel and bioethanol production.

The chalky soils are generally homogeneous and fertile. They infiltrate and store water very efficiently but can be prone to nitrate leaching into the groundwater. Nitrate concentration has been stabilised since the 1990s but can still rise to around 30 mg/l in the tap water locally. Nitrogen management is therefore a key issue for Benoit Collard and his neighbours. A specific approach has been designed in France for each crop with the help of very detailed experimental work from the state agronomic researchers at INRA, the applied research institutes, the nitrogen producers and local advisers.

Crop nutrition:

Photo LDAR Laon

Before sugar beet for example, a cover crop is first established to catch nitrogen (N) mineralised in the autumn. At the end of February, Benoit Collard pays around €40 to have each field systematically sampled at three depths to assess the quantity of mineral N available in the soil and to estimate potential N mineralisation. The software Azofert® has been specifically developed by the INRA local research station in Laon using regional references.

Following an application of poultry manure in the autumn followed by a cover crop, fertilizer nitrogen application can be reduced to 50 kg N/ha for the sugar beet compared to a maximum of 180 kg N without manure, for a targeted yield of 80 tonnes of roots per ha.

The Azofert® system is also used for N recommendation on potatoes and for spring malting barley which has a maximum protein content limit specified by the brewers. No nitrogen is applied in the autumn on rapeseed or winter wheat. Fertilizing with N starts in March and is applied in 2 to 4 split applications. An easy way to assess the quantity of N already taken up from the soil by rapeseed by the end of February is to weigh the biomass on some representative small plots. From this, a system developed by CETIOM (research institute for oil crops) allows the farmer to calculate the additional fertilizer N required by the crop according to his targeted yield and the local soil type. For wheat the N-Tester® system recommended by his co-operative adviser helps Benoit to maximise the N efficiency for yield and protein content while minimising the mineral N remaining in the soil after harvest.

Benoit Collard works with local advisers and with his neighbours to adapt the application of N fertilizers not only to each crop but also year by year, to the specific weather conditions. To achieve higher N recovery rates by plants, the soil must be in very good condition with well balanced nutritional fertiliity. Soil analysis is carried out every 5 years for each field, assessing P, K and Mg reserves as well as the availability of micronutrients.

Plans for progress and improvement:

With his neighbours, Benoit Collard intends to buy a new planter which will place some N and P fertilizer in specific zones in the soil to reduce the overall requirement for potatoes; they will possibly apply the same principle for the sugar beet crop.

Photo CETIOM

In 2005, he sowed grass buffer strips alongside all the water courses on the farm (according to GAEC obligations). In conjunction with hedgerows, this will offer an improved habitat for birds, increase biodiversity and improve the landscape. Benoit is looking for reliable tools that would help him and other farmers to make their own assessments in their fields simply by 'asking the plant' regularly whether it needs nutrients or not.

Stiewe Farm

GERMANY

The Stiewe farm was established in 1876, and the Stiewe family has managed the farm since 1991.

Germany country facts:

- Total agricultural output of 44.0 billion Euros, which represents 0.9% of country GDP, and 13.3% of total EU agricultural production.
- 412,000 holdings employ 592,000 people which represents 2.4% of total working population.
- Average farm size is 41.0 ha, with 36 cows on average on dairy farms.
- 17.02 Mio ha of agricultural land (47.7% of national territory), of which 61.8% is arable land and 29.1% grassland.
- 6.95 Mio ha of cereals, which represents 13.2% of total EU cereal area, and 1.51 Mio ha of oil and protein crops.
- 2.57 Mt of mineral nutrients in 2004/2005, corresponding to an average application of 112 kg nitrogen, 19 kg phosphate and 30 kg potash per hectare of agricultural land.

Sources : EU Commission, Eurostat, 2003 and 2004. EFMA 2004/2005.

About the farm:

The dairy farm is located 40 km south of Rostock. Intensive arable farming is mixed with extensive grassland and protected natural land, forests and lakes in this northeastern part of Germany. The average rainfall is about 570 mm. Hans-Günter Stiewe is responsible for the arable production and Karl-Heinz Stiewe looks after the dairy side of the business.

Size of the farm:

- 678 ha of agricultural land, of which 163 ha is grassland for grazing.

Crop rotation:

- Cereals and oilseed rape, on mostly sandy soils, with some forage maize.

Livestock:

- 240 dairy cows giving more than 9,000 litres / cow / year, with 180 calves and heifers.

Manure:

- 5,000 m^3 of slurry;
- 800 t of farmyard manure (FYM).

Workforce:

- 3 farm workers;
- 3 apprentices.

Farming system:

Hans-Günter has a strong focus on a continuous improvement of soil fertility and a good crop rotation mainly of cereals, forage maize and oilseed rape. The systems employed in both the dairy production and the arable farming is a realistic and reasonable mix of the most advanced and well-proven technology.

For cost-saving and soil conservation reasons the farm has increasingly adopted a low tillage arable farming system. Except for plant protection and fertilizer application, which are both regarded as tasks of the manager, most of the fieldwork including the harvest are outsourced to contractors. The yield potential of the mostly sandy soils is determined by the annual rainfall and its distribution. A key for the success of the entire farm operation is seen as the full implementation of a modern information technology system for data management. Each activity, whether in the stable or on the field, is recorded by computer and supported by modern software programs. All measurements in the field such as crop density and crop protection treatment will be stored immediately in the computer. Some observations are recorded together with their GPS referenced locations. All data including for instance soil analysis, crop biomass and nitrogen fertilizer application data derived from the Yara N-Sensor, and the variable yield data are combined in field data management software for documentation and decision support. The software can produce action lists with are sent to the farm manager's or the contractor's PDA for execution.

Crop nutrition:

Very important for the farm is the efficient management of organic fertilizers. All slurry and manure is spread either in autumn or spring with state of the art equipment to maximise the nutrient use efficiency. The slurry is applied with a trailing pipe technology in order to minimise ammonia volatilisation losses and to obtain an even spread on the soil surface. The average application rate of 10 to 25 m^3/ha results in an efficient use of the nutrients by the crop with little adverse effects on the environment. Before spreading, slurry samples are sent to a laboratory in order to determine precisely the nutrient content. The slurry application rate on the different fields depends on the nutrient level in the soil. This ensures the greatest efficiency of the nutrients and reduces the expenditure on mineral fertilizers. YaraPlan is the software, which is used for nutrient planning and calculation of nutrient balances. Special software calculates the requirement for all plant nutrients for each field according to the yield potential of the field. The gap between the nutrient demand of the crop and nutrients supplied by organic fertilizer and from the soil will be filled using mineral fertilizer. The Stiewe farm uses a Yara N-Sensor for topdressing nitrogen to cereals and oil seed rape. This technology improves the nitrogen use efficiency for the crops. It helps to achieve better yields with the appropriate N rate at each part of the field. The effect of the variable rate fertilizer application can also be demonstrated by an improved input-removal ratio for nitrogen, a balance calculation calculation required by law for arable production in Germany.

Plans for progress and improvement:

Hans-Günter and Karl-Heinz Stiewe strongly believe in the principles of good agricultural practice and integrated farm management. These principles will also steer the future development of their dairy farm in order to keep the Stiewe farm in good condition for the coming generations. They also apply nature and land conservation measures such as the establishment of 7 to 10 m wide strips of grassland alongside lakes and rivers, on which the application of fertilizers and agrochemicals is not permitted.

Uj Elet Company Farms

HUNGARY

Historical background:

At the end of the 1980s, approximately 10% of the total cultivated agricultural land in Hungary was under state control, 70% being co-operatively farmed, and 20% privately owned. Thus the privatisation of Hungarian agriculture was marked by the transfer into private hands of land and property assets which previously belonged not only to the state but also to the production co-operatives. By the end of 1998, almost the entire former co-operative land area and the majority of state land had been transferred into private ownership.

Hungary country facts:

- Total agricultural output of 6.6 billion Euros, which represents 3.1% of country GDP, and 2.0% of total EU agricultural production.
- 545,000 holdings employ 773,000 people which represents 5.3% of total working population.
- Average farm size is 6.0 ha, with 14 cows on average on dairy farms.
- 5.86 Mio ha of agricultural land (63.0% of national territory), of which 74.9% is arable land and 17.7% grassland.
- 3.00 Mio ha of cereals, which represents 5.7% of total EU cereal area, and 0,68 Mio ha of oil and protein crops.
- 0.50 Mt of mineral nutrients in 2004/2005, corresponding to an average application of 62 kg nitrogen, 12 kg phosphate and 17 kg potash per hectare of agricultural land.

Sources : EU Commission, Eurostat, 2003 and 2004. EFMA 2004/2005.

The Uj Elet Company manages 1,160 ha as a single arable unit, but which in fact comprises 45 separate farms, all within a radius of 25 km. Istvan Kriss is responsible for the production of maize and wheat and Janos Toldi for rape and sunflower.

About the farm:

The farm is situated in the central part of Hungary, 2 km from the Danube near the small city of Dunapataj and 20 km from the city of Kalocsa. The altitude ranges from sea level to around 90 metres and the annual rainfall is about 600 mm. The dominant soil types are river valley soil and compacted black earth (chernozem) and the region specialises in pepper production and in maize, wheat and sunflower.

Size of the farm:

- 1,160 ha, bringing together many separate farms with 45 owners.
- A third of the arable land is rented by the company from the Hungarian State (Kiskunsági National Park).

Main crops (2006):

- 380 ha winter wheat;
- 366 ha maize;
- 268 ha sunflowers;
- 122 ha lucerne;
- 8 ha rape;
- 6 ha pepper;
- 2 ha onion.

Soil types:

- Sandy alluvial river valley soil (near Danube);
- Compacted black earth (chernozem).

Workforce:

- A farm manager;
- 2 operations managers;
- 1 technical director;
- 21 full time employees.

Main machinery:

- 6 MTZ tractors;
- 2 John Deere tractors;
- 2 Claas combine harvesters.

Farming system:

The soil has a pH about 7.4, it is well drained and has a good yield potential. Cultivation techniques are chosen according to soil type and place in the rotation.

Rotations:

1. wheat-wheat-sunflower-wheat-wheat-maize-sunflower;
2. wheat-sunflower-maize-maize-wheat or sunflower;
3. wheat-lucerne-lucerne-lucerne-sunflower or wheat.

Many of the crops are grown on contract. The goal of the business is to achieve higher quality standards, and it is based on improved fertilization programmes and technologies, hard work and through specially organised and analysed field trials. A key to the success of the operation is seen as the step by step modernisation of the technical knowledge base and of the expertise of crop production in the field, leading to higher quality products and minimal environmental impact. After improving basic husbandry (through for example the introduction of NPK fertilisers), fertiliser spreader distribution patterns are being improved and the nitrogen applications optimised by using an N-Tester on the crop.

Crop nutrition:

The farm management and both operations managers believe in having a quality production system, part of this being to organise field trials and to carry out soil testing every 5th year. Soils are analysed for pH, P and K, as well as for Ca, S, Mg, Cu, B etc., in all analysing for 17 parameters. "The efficient use of nutrients is most important for us, because of the relatively high cost of the fertilizer."

It is expected that improvements in the fertilization programme should lead to higher crop quality and certainly to higher yields.

Using technologies which are new to Hungary, such as the N-Tester, helps with crop nutrition planning.
The N-Tester is a hand-held tool which enables quick and easy measurements of leaf chlorophyll to be taken at different growth stages of wheat to establish its exact nitrogen status and therefore requirement. This enables N applications to be varied from field to field, in conjunction with calculations based on previous cropping, soil type, etc. The result is more accurate field scale nitrogen recommendations, which improve profitability and minimise environmental effect.

Istvan and Janos know that, due to current limited financial resources for fertilizers and plant protection products, optimum crop performance cannot yet be reached. Nevertheless, the N-Tester has helped to optimise the use of their limited quantities of available nitrogen.

Plans for progress and improvement:

Istvan and Janos pay increasing attention to the following factors:

- Updating of technical background know-how, and new machinery for tillage;
- The organising of field trials and resulting improvement in plant production performance;
- Changing from a prilled to a granular source of straight nitrogen;
- Maintaining an open mind to new ideas;
- Achieving higher crop quality standards (e.g. protein content in winter wheat);
- Improving pest and disease control.

Measuring rape seed quality, and yield using load cells

The farm management strongly believes in the future for rape and maize. A growing market for oilseed rape for energy purposes is expected, in part due to a rapidly increasing demand for rapeseed oil for heating as substitute for fossil heating oil.

"Bio-ethanol and bio-diesel will be part of our future and we are looking to supply the planned new production plant near Kalocsa with our oilseed rape and hopefully also with our sunflower seed. We are pleased that a bio-ethanol plant is planned at Székesfehérfar, which is near Dunapataj. This will without doubt help our maize sales."

Koszanowo Dairy Farm

POLAND

Grzegorz Grudewicz runs the farm with his wife Krystyna and his parents-in-law. He has been the owner of the farm since 1995 when he took it over from his father-in-law, Tadeusz Kolowski.

Poland country facts:

- Total agricultural output of 14.3 billion Euros, which represents 3.1% of country GDP, and 4.3% of total EU agricultural production.
- 2,070,000 holdings employ 2,172,000 people which represents 17.6% of total working population.
- Average farm size is 7.0 ha, with 4 cows on average on dairy farms.
- 16.30 Mio ha of agricultural land (52.1% of national territory), of which 67.1% is arable land and 20.3% grassland.
- 8.38 Mio ha of cereals, which represents 15.9% of total EU cereal area, and 0.67 Mio ha of oil and protein crops.
- 1.70 Mt of mineral nutrients in 2004/2005, corresponding to an average application of 64 kg nitrogen, 23 kg phosphate and 26 kg potash per hectare of agricultural land.

Sources : EU Commission, Eurostat, 2003 and 2004. EFMA 2004/2005.

About the farm:

The farm is situated at Koszanowo, near Włoclawek in the centre of Poland, a region of rich arable land known as the 'larder of the country'.

Size of the farm:

24.5 ha, all owned by the farmer, with good lowland soils.

- 12 ha cropped for fodder and feed;
- 5 ha sugar beet (average yield 40 t/ha);
- 4 ha rapeseed (about 3 t/ha);
- 4 ha onions (average yield 30 t/ha).

Cattle:

- 16 milking cows;
- 12 young stock and calves;
- 9,800 kg of milk per cow.

Housing and manure:

- Straw bedded stable (see photo);
- Concrete pad for farmyard manure (FYM);
- Tank for slurry storage.

Farming system:

All replacement heifers for the herd are home-bred. The cattle are fed with maize silage produced on the farm, together with bought-in high-protein hay and with concentrates. This is supplemented with silage made from sugar beet tops. Concentrates are produced using home-grown cereals (wheat and barley as bruised grain), with wheat bran, soya bean, rape seed and mineral-vitamin mixtures being purchased. Daily intakes are determined individually for each milking cow and the herd is under regular veterinary supervision. The milk produced is of exceptional high quality. Field operations are completely mechanised, using the farm's own equipment. Typical crop rotations include sugar beet or onions followed by spring barley, rape or silage maize and then wheat.

Crop nutrition:

Grzegorz Grudewicz integrates the use of both stable manure and slurry with mineral fertilizers. Storage of farmyard manure has been improved with the building of a concrete pad and the slurry is collected into a tank. This investment benefited from some EU aid. Farmyard manure is applied in the spring before the sugar beet crop at around 40 t/ha on 5 to 6 ha each year. The overall nutrient requirements of the crop are then balanced using mineral fertilizers. Analysis for soil fertility (reserves of phosphorus and potassium and the pH) are carried out every year by certified laboratories. Applications of fertilizers are determined based on the result of these soil analyses and according to crop requirements. Ammonium nitrate and calcium ammonium nitrate with magnesium and sulphur additives are the main nitrogen fertilizers (with sulphur because of the local deficiency) as well as multi-nutrient compound mineral fertilizers (NPK), also containing magnesium and sulphur according to need.

Typical fertilizer rates applied on the farm are as follows:

Crop	N	P_2O_5	K_2O
	kg/ha	kg/ha	kg/ha
Forage rape	200	80	120
Forage maize	150	110	200
Wheat	120	100	120
Barley	90	80	100
Onions	180	120	160
Sugar beet	120	110	130

An average consumption of fertilizers:

- Ammonium nitrate – 5 t/yr.
- Calcium ammonium nitrate – 5 t/yr
- Multi-nutrient mineral fertilizers – 10 t/yr.

Grzegorz Grudewicz uses a centrifugal twin-disc spreader with a 27 metre bout width. He also regularly applies lime to the soil to maintain a suitable pH using a spreader designed for powdered material. Thanks to good co-operation with the local supplier he does not have to store fertilizers on the farm; they are stored in the supplier's warehouse and delivered when needed.

Plans for progress and improvement:

Grzegorz Grudewicz's farm has co-operated fruitfully with the Agricultural Advisory Centre in Zarzeczewo near Włoclawek for several years. Such contacts have included advice on organic manure management and use, training and advice on soil cultivation options, fertilizer policy and types applied and cattle production, as well as in the range of adjustments required to meet EU standards and generally advice on agri-business. Leszek Piechocki from the Agricultural Advisory Centre at Zarzeczewo has liaised with this farm for over thirty years. The farmer also takes advantage of training offered by the creamery, which also provides veterinary assistance. The farm meets all sanitary and animal health requirements and has been certified by the State Veterinary Surgeon in Włoclawek for many years. It also meets the demands of the Code of Agricultural Good Practice, which is certified by Leszek Piechocki.

Expected developments:

Grzegorz Grudewicz intends that the farm should continue to make progress. In the near future he plans to equip the cow-shed with a pipe-line milking system and a bigger milk tank. He also intends to increase his herd size, unfortunately only up to 18 milking cows due to the limits of his milk quota. He would also like to extend the land area of the farm land, but there are no fields for sale in the vicinity. Investment in manure storage will be completed by having his own equipment for spreading liquid manure, which will allow the saving of nutrients and more even application of them to his fields.

Los Montesinos Farm

SPAIN

The farm is run by Salvador Garre Garcia, in collaboration with his two brothers Pedro Manual and Jose Antonio. They inherited the farm from their father and decided to run it as a family company to avoid splitting it into small units.

Spain country facts:

- Total agricultural output of 43.8 billion Euros, which represents 3.4% of country GDP, and 13.3% of total EU agricultural production.
- 1,016,000 holdings employ 1,141,000 people which represents 5.5% of total working population.
- Average farm size is 22.0 ha, with 18 cows on average on dairy farms.
- 25.25 Mio ha of agricultural land (50.0% of national territory), of which 37.0% is arable land and 29.9% grassland.
- 6.46 Mio ha of cereals, which represents 12.3% of total EU cereal area, and 1.43 Mio ha of oil and protein crops.
- 2.03 Mt of mineral nutrients in 2004/2005, corresponding to an average application of 46 kg nitrogen, 25 kg phosphate and 21 kg potash per hectare of agricultural land.

Sources : EU Commission, Eurostat, 2003 and 2004. EFMA 2004/2005.

About the farm:

In the village of Sucina in Murcia, south east Spain, the farm is 15 km from the Mediterranean coast. This region, known as Campo de Cartagena, specialises in vegetable production in open field and greenhouses, and in citrus. Average rainfall is 200-250 mm, mainly in spring and autumn.

Size of the farm:

50 ha of citrus orchard with production of:

- 3 ha early season lemons;
- 15 ha early season oranges;
- 8 ha mid-late season oranges;
- 9 ha late season oranges;
- 8 ha late season mandarins.

Soils:

- Loamy clay, prone to erosion during heavy rainfall;
- Organic matter 1.24%;
- Alkaline (pH 8.0).

Water available from different sources:

- Private well;
- Collected from rainfall in a large reservoir (75,000 m^3);
- Main canal 'Tajo-Segura' on a quota basis and in variable amounts each year.

drip-irrigation and fertigation system:

- Head unit is an automatic system, with individual injection for the different liquid fertilizers stored in tanks.

Farming system:

The Murcia area has meteorological stations covering the main agriculture areas. Daily information on temperatures, humidity (maxima, minima, averages and absolute values), wind, rainfall, radiation and evapo-transpiration (ETo) is readily available via internet connection. All these data are used for the assessment of irrigation water requirement on a daily basis. Tensiometers are located in plots to monitor water deep percolation of water for the adjustment of the amount of water applied locally. In the case of deep percolation, irrigation is split into two applications per day if needed. As a guide, water consumption for the

different crops is 4,000 m^3/ha for lemons, 3,500 for oranges (Nave Late and Navelina) and mandarin, and about 3,000 m^3/ha for the orange Navel Powel, with an approximate total annual water consumption of 150,000 m^3 for the farm. Water from the reservoir is analysed regularly to assess quality for fertigation.

Trees are planted on small hills across the main slopes for a number of reasons:

a) Prevention of soil erosion during heavy rainfall events, because water does not run down the slope.
b) Better usage of water, because hills have better water penetration due to being less compacted. Also it improves the water-air relationship in the root zone.
c) Prevents water-logging close to the main trunk (which has high permeability) so reducing the incidence of diseases.
d) Improves early root development of young trees.
e) Under saline conditions it facilitates the leaching-out of salts.

Two dripper lines for every tree row assure balanced growth on both sides of the trees, with 6 drippers per tree for oranges and mandarins and 8 drippers per tree for lemons. The EC (electro-conductivity of the fertigation solution) is controlled in the central unit and the pH is adjusted using nitric acid, to get an optimum pH for plant nutrition of 6.2.

Crop nutrition:

- Liquid fertilizers are used with the application of a complete N-P-K-Ca-Mg throughout year, with changing proportions depending on the growth state and with every plot being adjusted for its own equilibrium of nutrients.
- The preferred N form is nitrate, with a maximum of 20-30% as ammonium-N.
- Calcium application is on a continuous basis, even on these soils which are rich in calcium, showing that proper cation balances are key, especially when high rates of N and K are applied, to achieve required quality parameters. Peel strength is also important in late season varieties and fruit with a long handling process, as is the case for citrus in Spain.
- Micro-elements are also applied. Iron as Fe chelate EDDHA during spring and early autumn (a short period with higher concentration performs better than a low concentration for a longer time).
  Zn and Mn if needed are applied in early spring as foliar sprays for best performance and so as not to cause any antagonism with other nutrients.

Plans for progress and improvement:

Development of leaf tissue analysis on an annual basis to check nutritive status and to plan the fertilization scheme for the next season. Sampling is made in late November-December, taking leaves from last spring flush on branches with no fruits, and uniformly inside each plot. Tree nutrition is of paramount importance for building fruit quality. Improving fertigation techniques allow for extremely precise timing and for the adjustment of nutrient applications to match the need of each variety and field.

JSR Arable Farms

UK - ENGLAND

Philip Huxtable is the technical director for JSR Arable Farms as part of his wider responsibilities within the group.

About the farm:

As part of the JSR Farming Group, JSR Arable Farms is responsible for 3,600 ha of land in the county of Yorkshire, England. The business comprises 8 separate arable farms within a 40 km radius, but is managed and operated as a single farm unit. The area is characterised by large rolling arable fields divided by steep grass valleys. Height ranges from sea level to around 150 metres and the annual rainfall is around 625 mm.

Size of the farm:

3,600 ha in 8 separate farms

Arable land:

The wide range of soils means that there are different rotations suiting different areas of the farm, leading to quite complex cropping. In 2005 this comprised:

- 1350 ha winter wheat;
- 300 ha winter barley;
- 310 ha winter oilseed rape;
- 310 ha vining peas;
- 180 ha winter beans;
- 30 ha spring beans;
- 180 ha potatoes;
- 36 ha sugar beet;
- 30 ha temporary grass;
- 270 ha set aside.

Other land area:

- 25 ha short rotation coppice (SRC);
- 170 ha permanent grass;
- 180 ha 'stewardship' areas.

The arable staff:

- A farms manager and 9 full time men,
- Supplemented by seasonal and casual labour.

UK country facts:

- Total agricultural output of 24.7 billion Euros, which represents 0.7% of country GDP, and 7.5% of total EU agricultural production.
- 281,000 holdings employ 301,000 people which represents 1.3% of total working population.
- Average farm size is 57.0 ha, with 79 cows on average on dairy farms.
- 17.07 Mio ha of agricultural land (69.9% of national territory), of which 26.1% is arable land and 65.6% grassland.
- 3.13 Mio ha of cereals, which represents 6.0% of total EU cereal area, and 0.85 Mio ha of oil and protein crops.
- 1.68 Mt of mineral nutrients in 2004/2005, corresponding to an average application of 67 kg nitrogen, 16 kg phosphate and 22 kg potash per hectare of agricultural land.

Sources : EU Commission, Eurostat, 2003 and 2004. EFMA 2004/2005.

Farming system:

There is a wide range of soil types on the farms, but the dominant type is shallow clay soil with chalk and flint over a chalk base. The lower lying farms can have boulder clay, sandy clay loams and even some gravel.

The business is based on sound principles of quality production, development of people and continuous improvement through innovation, technology and hard work. There is a strong environmental focus on the farms and the home farm became a demonstration unit for LEAF in 2001. In addition to the crops, the arable farms have the use of the output in terms of slurry and manure from JSR Pig Production, which has 2,100 sows and their progeny taken to bacon. Many of the crops are grown on contract - potatoes for crisps and pre-packed market, vining peas for Birds Eye (for which the completion of the LEAF Audit is mandatory) and malting barley grown to nitrogen specification. Cultivation techniques are chosen according to the soil type, the place in the rotation and the local conditions. The soil structure is assessed to determine the need for sub-soiling, but most of the combinable crops will be established using a min-till system which helps to conserve moisture. Ploughing is used for spring planted crops.

Crop nutrition:

Soil testing for pH, P, K and Mg is performed routinely and phosphate and potash applications are adjusted according to soil status and whether the field has received pig slurry. A system of deep testing (45 cm) for phosphate and potash has been used on some fields with the results fed into the variable rate spreaders to make more efficient use of these nutrients. The entire farm is situated within a Nitrate Vulnerable Zone (NVZ) and recently investment has been made in extra slurry storage to allow better use of the nutrients on farms that do not have pig units. Slurry separation across the farms means that high dry matter material can boost organic matter content when used, leaving low dry matter (typically 3-4% dry matter) for spring application. Manure and slurry are targeted towards lower fertility fields and the emphasis is on slurry applied as a top dressing to winter cereals using an umbilical pipe system rather than tankers. The nutrient content of the slurry is assessed using a Quantofix analyser and it may be applied in autumn or spring – as late as GS 31 on wheat.

Plans for progress and improvement:

Remote sensing of crops for colour intensity has resulted in more accurate assessment of slurry value and allowed application of manufactured nitrogen to be varied. This has led to more uniform crops and more efficient use of nitrogen. The overall nitrogen rate required is based on guidelines provided by government fertilizer recommendations (RB209). These take into account the soil type, previous cropping and winter rainfall. However, these are then adjusted according to the yield potential of the crop, end market requirements and nutrient applied from slurry. Soil mineral nitrogen tests are sometimes used as a guide, but increasingly as an assessment of the general status of soils in comparison to other years. Most sensitive environments have a buffer strip of grass protecting them and border attachments on the fertilizer spreaders and training of staff has led to protection of these features of the farm.

Mas Saint Jean Vegetable Farm

FRANCE

Jean-Pierre and Mireille Duez are both qualified agronomists and began their careers as farm advisers. In 1982 they moved from the north to the south of France, near Montpellier. They have three children and manage the farm themselves.

France country facts:

- Total agricultural output of 64.8 billion Euros, which represents 1.9% of country GDP, and 19.6% of total EU agricultural production.
- 614,000 holdings employ 959,000 people which represents 4.0% of total working population.
- Average farm size is 45.0 ha, with 36 cows on average on dairy farms.
- 29.63 Mio ha of agricultural land (54.0% of national territory), of which 47.9% is arable land and 42.3% grassland.
- 9.33 Mio ha of cereals, which represents 17.8% of total EU cereal area, and 2.27 Mio ha of oil and protein crops.
- 3.89 Mt of mineral nutrients in 2004/2005, corresponding to an average application of 81 kg nitrogen, 26 kg phosphate and 34 kg potash per hectare of agricultural land.

Sources : EU Commission, Eurostat, 2003 and 2004. EFMA 2004/2005.

About the farm:

Starting with 3.2 ha in 1982 the Mas Saint Jean farm at Lansargues now extends to 123 ha, specialising in melons, salad and early cherry production.

Size of the farm:

123 ha arable land.

Main crops:

- Wheat and sunflowers;
- Rapeseed for biodiesel production at a new plant nearby;
- 30 ha melons of which 5 ha is protected under plastic tunnels in rotation with 5 ha salad;
- New 3.5 ha cherry orchard covered with plastic in spring for early production.

Workforce:

- In addition to the owners, the farm employs 5 permanent workers and part time employees to pick cherries, melons and salad.

Certification:

- Jean-Pierre and Mireille qualified in 2006 for the national "***Agriculture Raisonnée***" integrated management programme and at the same time obtained the EUREPGAP certification for melons (required for sale to large distributors).

Farming system:

The flat coastal plain has for a long time been dedicated to wine production in this Mediterranean climate but the crisis in the wine sector has forced

many farmers to uproot their vineyards. Jean-Pierre now crops these fields with melons and salad, using fertigation and producing high-quality products. Melons are cropped in rotation with rapeseed, wheat and sunflower to avoid the development of diseases.

The farm liaises with different specialist grower organisations or co-operatives not only for marketing the melons, salad and cherries but also for the wheat and sunflower grain and the rapeseed for delivery to the biodiesel plant.

The coastal plain is classified as a nitrate vulnerable zone for the protection of the groundwater, which is a source of drinking water.

Crop nutrition:

Soil fertility is generally poor after many years as a vineyard, with low organic matter and low nutrient reserves. Regular soil analysis is essential to manage the new fertilizer policy. To re-stimulate the biological activity in soils, sorghum is sown after the melon crop as a green manure to be ploughed into the soil, followed by an application of 30t/ha of compost.

Fertigation of the melon crop is essential for the good quality of the fruit and to protect the environment. The composition of the nutrient solution can be adjusted on a day-to-day basis for each individual nutrient. The Pilazo® system developed in France (nitrate analysis in the petiole sap) is used every week on the farm to adjust the nitrogen in the solution precisely to the crop needs, thus avoiding over- or under-supply.

For wheat the GPN® system (reflectance of light from the foliage) is used to decide on the timing and the quantity of the third or fourth application of N on wheat (high-protein varieties being grown). Jean-Pierre discusses the results with his advisor and also takes into account the weather forecast and his own experience.

Nobody can be an expert in all situations and crops! Jean-Pierre looks for information and advice from different specialist advisors for his melons and salad, and more recently for his early cherry production.

Plans for progress and improvement:

Irrigation is limited to melons and sunflower. The experience gained from the micro-irrigation of the melon crop is being transferred to the sunflowers. A new irrigation tape system (low pressure water delivered between the rows of sunflower) dramatically increases water use efficiency when evapo-transpiration rates are high.

The rapeseed crop area will increase from 24 to 49 ha in 2007 to supply the new biodiesel plant situated 60 km from the farm. This crop needs no irrigation, is very efficient at extracting residual N after the melon crop and also protects the soil from the heavy winter rains in this region.

The overall objective is careful crop production, using the best techniques to help improve soil fertility and to protect the environment, while preserving food quality and profitability.

Notes :

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