5 Nutrient management - crops

Context

5.1 Naturally, nutrients essential to plant growth become available through animal deposition (dung and urine), atmospheric deposition, 'fixation' by certain plants, or by the weathering of minerals within the soil.

5.2 Most agricultural and horticultural crops show predictable increased growth and productivity in response to applied fertilisers.[1] Major nutrients such as nitrogen (N), phosphorus (P) potassium (K), sulphur (S) and magnesium (Mg) are commonly applied as inorganic fertiliser, along with lime which is used to buffer both the natural acidity of many soils and the acidifying effect of nitrogen fertiliser.

5.3 Eutrophication of semi-natural habitats and watercourses from agricultural run-off affects approximately 17,800 ha of SSSIs in England.[2] Maps produced by the Environment Agency show that regions where arable farming is dominant (Anglian, Midlands and Thames) have the highest proportion of river length with excessive nitrate and phosphate levels.[3]

Current practice

5.4 In agricultural terms, maintaining soil fertility to meet crop requirements is a key element to successful and profitable crop management. Agricultural crops show predictable responses in development and yield to the addition of nutrients. Fertiliser recommendations are based on identifying a particular crop's economic optimum (the point at which the increase in value of the crop is no greater than the increase in the cost of the nutrient).[4] In the case of phosphates, movement through the soil does not take place easily, so it has often been seen as expedient to apply more than is needed by the plant.[5]

5.5 The value of inorganic nutrients for agricultural production is invariably calculated in economic rather than environmental terms. With increasing pressures, both regulatory and/or financial, good nutrient management is becoming increasingly important. Organic fertiliser (particularly farmyard manure and slurry) is often undervalued and on many farms a product that can save cash outlay is wasted.[6] See also chapter on 'Nutrient and pollution management - intensive livestock'.

5.6 Organic farming systems are equally demanding of nutrients if economic yields are to be achieved. Nutrient supply to organic farming systems relies on the bulk of the nitrogen coming from biological fixation by legumes and on phosphate supply being mediated by mycorrhizal (fungal) associations with the roots of most crop plants.[7] Livestock wastes (farmyard manure (FYM) and slurry) are also used as nutrient inputs and also, occasionally, external nutrient sources such as rock phosphate.

5.7 Of the farms surveyed in Defra's Farm Practices Survey (2007), nearly 24% of those who grew crops did not have any nutrient management plan.[8]

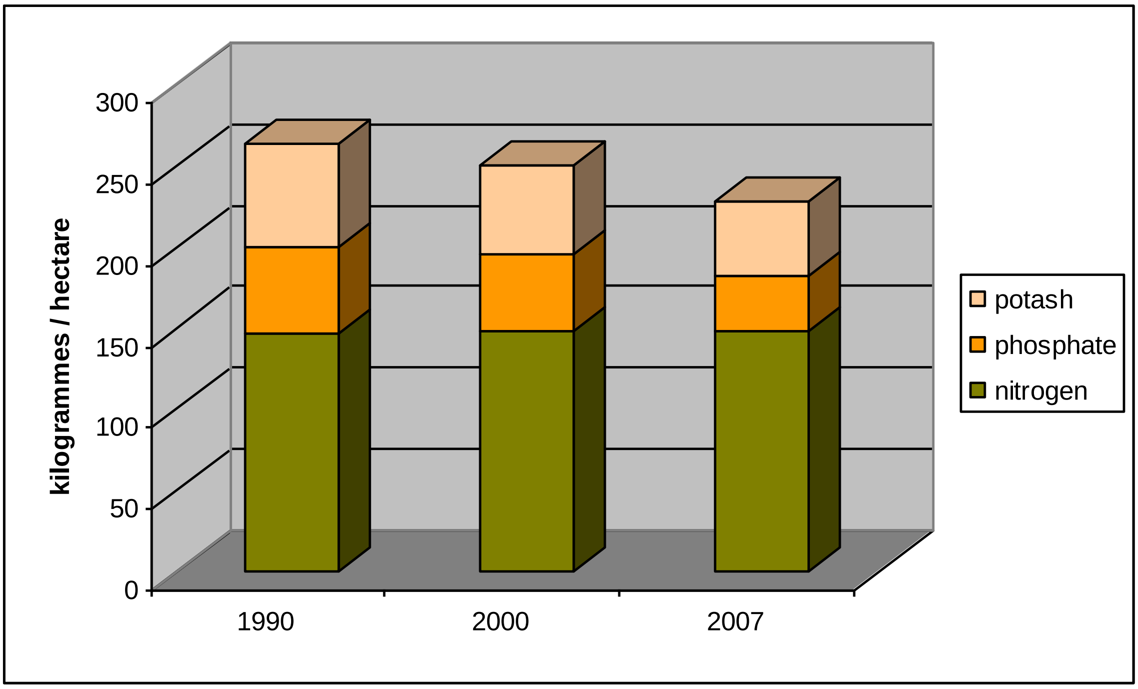
Industry trends

5.8 In environmental terms, good nutrient management ensures that a wide range of factors are taken into account prior to producing a fertiliser recommendation. These factors include nutrients from the soil supply, recent applications of organic manures, previous cropping, reduced winter rainfall and the estimated yield and quality parameters. Soil type has a strong influence on the natural availability or ability to retain nutrients,[9] thus appropriate quantities, rates and timings of nutrient application can vary considerably across individual catchments and even holdings. Therefore, responsible fertiliser and manure use must be based on a field-by-field knowledge of nutrient inputs and off-takes so that nutrient balances can be calculated. Taking full account of all inputs helps minimise the environmental impact.

5.9 A wide range of manures/wastes (organic and inorganic) may be applied to land for example, FYM, slurry and poultry manure, sewage sludge, composts, paper wastes, recovered gypsum, incinerator ash and other products. These have a lower cost (financial and environmental) in terms of production but are less consistent in their content and generally release their nutrients more slowly, making them more difficult to use effectively and efficiently.[10] The practical difficulty of achieving high rates of nutrient supply in organic systems is one factor contributing to arable cash crop yields that are typically between 20% and 40% lower, and forage crop yields 20% lower than on conventionally fertilised farms.[11] Some waste products (such as sewage sludge) cannot be used on organic land.

5.10 Fertiliser prices have risen sharply over the past year and land managers have responded by looking for ways to further reduce waste, after a number of years of reduction of fertiliser use. This has involved either a reduction in quantity used, or a more effective targeting of what is used, and in some cases both. An improvement in river water quality throughout much of the country has coincided with this change.[12]

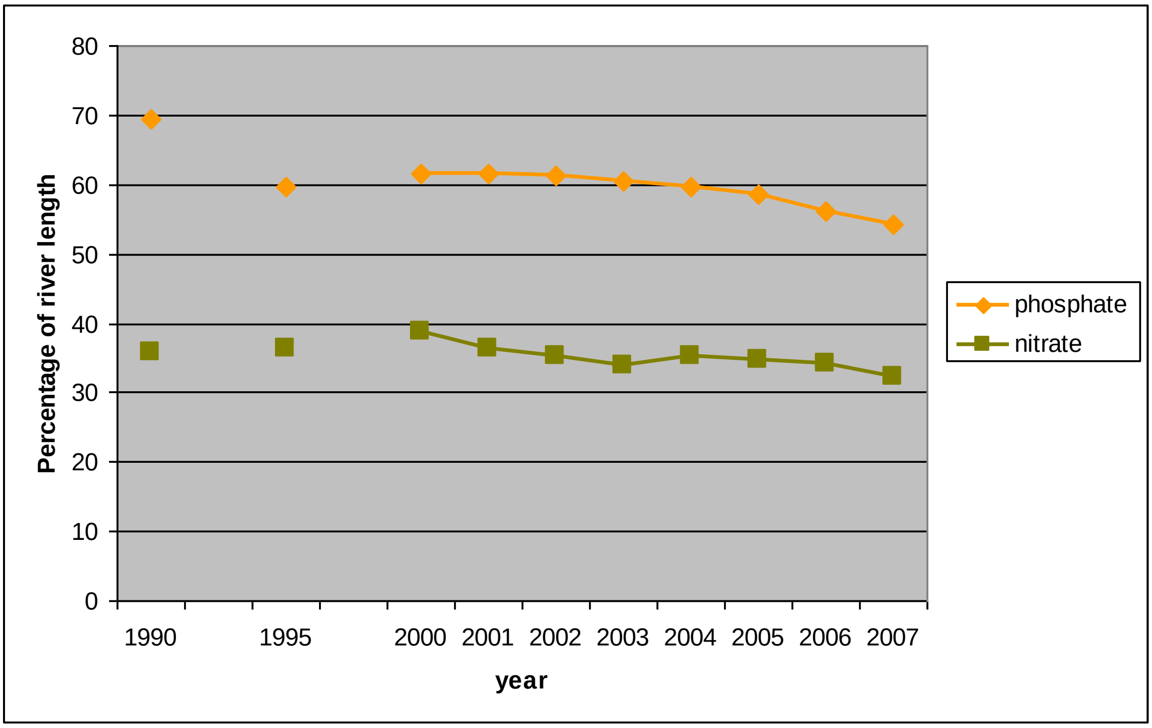
5.11 Figure 3 illustrates the reduction in fertiliser used on arable crops, particularly phosphates, since 1990.



Source: British Survey of Fertiliser Practice[13]

Figure 3 Average fertiliser use on arable crops in England, 1990-2007

5.12 Figure 4 shows that the reduction in fertiliser use nationally can be correlated with the reduction of river length identified by the Environment Agency as having 'high levels of nutrients'.[14]



Source: Environment Agency[15]

Figure 4 Indicator - Rivers with high levels of nutrients in England, 1990-2007

5.13 For current incentives, advice and regulation for nutrient management, see Annex I to this chapter.

Key impacts

5.14 Native plant species and assemblages respond unevenly to the addition of nutrients.[16] In semi-natural habitats such as grasslands,[17] and for many arable wildflowers,[18] the deposition of additional nutrients can allow some species to out-compete others, and can also compromise disease or pest resistance, resulting in medium to long-term habitat modification or loss.[19]

5.15 Nutrients which are not taken up by plants or absorbed into the soil biomass are diffused either aerially or in water. Problems involving nutrients being released by agriculture and affecting semi-natural habitats and native species are centred around excessive levels of nitrogen (as nitrate, nitrite or ammonium) and phosphorus (as phosphate), which enter watercourses and groundwater, and airborne nitrogen (as nitrous oxide and ammonia).[20]

5.16 In many agricultural systems, the application of fertilisers to crops results in nutrient movement beyond the crop edge or rooting zone. This has a nutrifying effect on hedgerows, boundary habitats[21] and the plant communities of receiving waters, where nitrates and phosphates are transported through the soil profile or by surface flow. Most manures and waste products are applied for their value in terms of additional nitrogen or organic matter. The nitrogen/phosphate ratio in these materials is generally such that it can lead to over-application of phosphate. Whilst phosphate is generally held in the soil, it can also reach a level of saturation, beyond which it will leach through, resulting in contamination of water-courses.[22] A further disadvantage of using manures and waste products is their potential to contain heavy metals, which can accumulate in the soil[23]. See also chapter on 'Nutrient and pollution management - intensive livestock'.

5.17 Cultivations can be an important source of mobilised nitrates, as mineralised nitrogen in the soil is released.[24]

5.18 For further factual background to this section, see Annex II to this chapter.

Summary of impacts

Biodiversity

5.19 Research has shown that inorganic fertiliser has a negative effect on many native grassland and arable plant species and assemblages. This can have a long-lasting effect due to the slow transport of phosphorus out of soils.

5.20 Increased deposition of nutrients on natural and semi-natural vegetation will result in a change in species composition, either due to the increased growth of some species, or because of an increase in susceptibility of other species to disease or climatic extremes, for example frost hardiness.

5.21 Habitats such as woodlands, wetlands and semi-natural grasslands adjacent to intensively cropped areas can be affected by nutrients in surface or groundwater.

5.22 Nutrient deposition into watercourses and groundwater can affect rivers, standing water, and coastal and marine waters. Aquifers can also carry nutrients in groundwater to fens, affecting their botanical structure.

Resource management

5.23 Regions where arable farming is dominant (Anglian, Midlands and Thames) have the highest proportion of river length with excessive nitrate and phosphate levels.

5.24 Excess nutrients in the soil can be dispersed aerially as greenhouse gas (N_2O) or ammonia, which can result in nitrogen deposition elsewhere, or they can be transported in water, leading to eutrophication in water and loss of aquatic flora and fauna.

5.25 The use of buffer zones at field boundaries and of catch crops are two key ways to minimise nutrient leaching and volatilisation. The rapid incorporation or injection of organic manures is an important method for mitigating ammonia emissions.

5.26 The rise in price of inorganic fertilisers is likely to increase the pressure on land managers to minimise in-field losses, by tailoring applications more closely to crop needs and by enhanced soil management.

Greenhouse gases

5.27 Nitrous oxide is released at manufacture and mineralistation of inorganic fertilisers. Carbon dioxide is released at manufacture, transport, and application of inorganic fertilisers (particularly of nitrogen fertiliser). Methane may also be released where organic fertilisers are used. See chapter on 'Nutrient and pollution management - livestock'.

Landscape

5.28 Current global trends suggest that the pressure on productive agricultural land is unlikely to diminish in the future, leading to a probable intensification in crop production and pressures to increase the area of cultivated land.

Annex I Current incentives, advice and regulation

There are various drivers forcing agriculture to move towards better control of nutrient losses to water and air. They include the Water Framework Directive, legislation protecting special wildlife sites and international carbon emission obligations.

Agri-environment arable-reversion options stipulate zero nutrient input where a high diversity of native plant species is part of the objective. There are other options which incentivise the use of low inputs.

The Code of Good Agricultural Practice[25] provides an industry standard for soil water and air management.

The current England Catchment Sensitive Farming Delivery Initiative (ECSFDI) provides a ‘toolbox’ to give advice on meeting some elements under the programme of measures in the Water Framework Directive.

A number of regulatory instruments are applicable to the use of fertilisers and crop nutrients:

- *Wildlife and Countryside Act (1981)*[26] *and the Countryside and Rights of Way (2000)*[27] *Act*. Application of nutrients to designated sites such as SSSIs may be considered an Operation Likely to cause Damage which is an offence under this legislation.
- *EU Groundwater Directive 2006.*[28]
- *Water Framework Directive 2003*[29], the English legal instrument of the European Water Framework Directive (2000).[30]
- *Nitrate Pollution Prevention Regulations 2008*.[31]
- *Nitrate Vulnerable Zone* regulations[32] (currently applied to nearly 70% of England and Wales).

Annex II Impacts on environmental sustainability of crop nutrient management

Table 6 Impacts on environmental sustainability of crop nutrient management

Habitat quality and diversity	• Low nutrient status is important where maintenance or recreation of semi-natural habitats is the objective. Species rich grasslands and lowland heath both require low levels of nitrates and phosphate. These habitats can be adversely affected by nutrients entering the system.[33] • In current conventional agricultural systems, nutrients not taken up by crops, or held in the soil leach into the water, or (in the case of ammonia and N_2O) are released into the atmosphere, from where they may disrupt the equilibrium of nutrient cycles in other habitats. This can result in some species out-competing others, thereby changing or degrading the habitat.[34,35] • Nitrates and phosphates can be taken up by algae and some aquatic plant species, which are then able to proliferate vigorously and seriously affect habitats and water quality downstream, and into the sea.[36] • Semi-natural habitats downwind or downstream from an area of nutrient release can be adversely affected, generally by a disruption of the species balance, or the incursion of new species.[37]
Species abundance and diversity	• Serious eutrophication can result in the majority or all aquatic life in affected waters being killed, due to the massive oxygen demand of developing algae.[38]
Sediment loads in water	• Phosphates get into watercourses via movement of soil particles to which the phosphate is bonded. It is therefore an important consideration in the downstream effects of erosion. Phosphates can also move in soluble form, and movement can be overland flow, subsurface flow, through drains etc.[39]

Table continued...

Nutrient loads in water	• Nitrates enter water mostly through leaching, which can come from inorganic fertiliser, organic manures, and also can be released by legumes such as clover. Phosphates enter water predominantly via physical removal when attached to eroded soil particles, though some can arrive in solution.[40] • High concentrations of nitrates in water occur mainly in the central and eastern regions of England,[41] which coincides with the predominance of arable farming. • It is estimated that between 25% and 40% of the phosphates in water courses is due to agricultural run-off and soil erosion (lower than previously estimated).[42,43] • Polluted waters may take a significant time to return to an accepted nutrient status.[44] • Nitrates which are not taken up by plants can leach into groundwater. This can take years to flush out, and can be transported a long way from the original source of the discharge.[45] • Nitrate release by organic matter is gradual, unlike inorganic fertiliser. When it forms part of organic matter it is less susceptible to leaching in high rainfall events, but release is generally gradual and can be more difficult to match to crop requirements.[46] • Between 1990 and 2006 the percentage of rivers of good biological quality in England rose from 60% to 71%. In 2006, 66% of English rivers were of good chemical quality, compared with 43% in 1990.[47]
Greenhouse gases	• CO_2 and N_2O are released during the manufacture of inorganic fertiliser.[48] • N_2O is a bi-product of the nitrogen cycle, released by the denitrification of ammonium nitrate fertiliser, manures and slurries. It is a GHG which is approximately 310 times more potent than CO_2, although it can break down over time in sunlight.[49] • Organic fertilisers can release large quantities of methane if not managed properly.[50] • More than 50% of the total anthropogenic N_2O emissions in the UK come from agriculture.[51] • N_2O emissions from agriculture in England have decreased by almost 22% since 1990, mainly due to a reduction in fertiliser use.[52]
Air quality: other pollution	• Organic fertilisers are a common source of odour nuisance. • Application of organic manures (particularly slurry and FYM) can result in high losses of N as ammonia (*c.*40% for slurry, 70% for FYM).[53]

Table continued...

Soil function	•	The use of heavy machinery to apply nutrients in the form of inorganic and organic fertilisers can lead to problems of compaction, particularly in the spring.[54]
	•	The chemical make-up of the soil can be affected by fertiliser application in terms of its pH, as well as changes in terms of possible addition or loss of elements and compounds.[55]
	•	Chemical and physical changes to soils, such as acidification caused by application of inorganic fertilisers, and heavy metal contamination from fertiliser and organic matter can affect soil microflora and fauna.[56] [57]
	•	Crop uptake of mineral nitrogen may not be much greater than 50%,[58] although some nitrogen may become immobilised in the soil biomass, for example micro-organisms, fungi, bacteria.
Landscape character	•	Nutrient use has enabled land managers to intensify production. This has involved a change in agricultural landscapes, particularly where it has allowed poorer land to be used for economic production. For example, in Breckland, acid heathland has been ploughed since the Second World War and intensively managed. Now much is in irrigated vegetable production,[59] on ALC Grade 4 land.

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Case study: Precision farming

Precision farming is a relatively new application of Global Positioning System technology developed over the last twenty years. It enables farmers to map to a relatively high degree of accuracy variations in crop yield within individual fields. Where these variations are closely related to permanent or long-term physical features, there is the potential to adjust fertiliser and spray inputs accordingly. This has the advantage of targeting products better to where they are needed most, and also avoiding waste where crop uptake is in some way limited, allowing potential nutrients to be washed away.

The initial cost of such technology can be high - it requires harvesting equipment which measures and maps grain flow as it is being harvested, and automatic steering systems for tractors, to ensure that the correct fertiliser or spray dosage is applied in the correct place. Possible prices range from £4500 to £16,000 for an integrated system, depending on the accuracy required, and whether it is retro-fitted to existing equipment. Early calculations suggest that low-cost systems could be worthwhile for arable areas over 80 ha, and for higher cost systems, areas may need to be 250 ha or more.[1]

Currently crop yields are predominantly mapped using equipment on the harvesting machinery which measure changes in yield through the field at the point of harvest. This is a relatively cheap way of mapping crop information, but variability in yields over a field may have a number of potential or actual causes, for which better fertiliser targeting may not be the answer.

Potentially crop treatments need not be based on data collected from previous harvests, but they can be determined from remote sensed images, using hyperspectral data for the estimation of various biochemical parameters of vegetation, such as leaf chlorophyll and nitrogen concentrations.[2] Use of such imagery is currently costly, and the scale of operation required to see benefits valuable enough to offset these costs may mean that relatively few enterprises are likely to adopt the technology in the short term.An even more targeted use of agro-chemical products could further reduce pressures on the natural environment.

In the Lincolnshire Coastal Rivers Catchment, farmers have become engaged in issues around resource protection through their interest in minimising unnecessary spray and fertiliser applications[3] This has led to an improved awareness of resource protection relating to farming activities, many of which can be immediately addressed by use of precision farming systems. Where expensive products such as fertilisers are being more effectively targeted, there are clear opportunities to improve financial margins.

The use of precision farming technology has thus far been directed predominantly at symptoms and criteria relating to growing crops. It could be argued that soil condition and function is also worthy of attention, and could render some chemical-based treatments unnecessary.

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