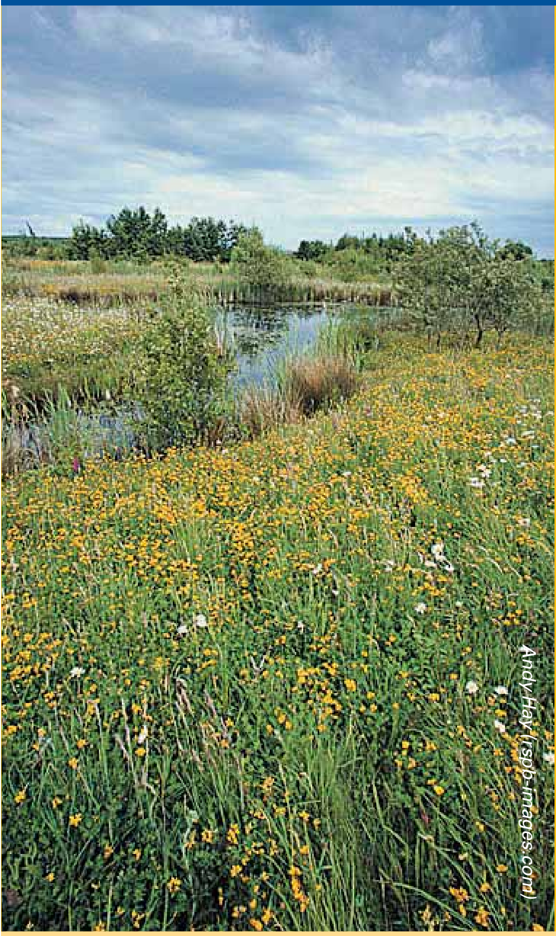
BETTER LAND FOR BETTER WATER: Scenarios for change

Modelling changes in agriculture to improve water quality in England



BETTER LAND FOR BETTER WATER: Scenarios for change

Modelling changes in agriculture to improve water quality in England

J Shi, R Davis and J Densham

February 2006

This document is a summary of a full project report: Shi, J, Davis, R and Densham J (2006) Better Land for Better Water: Modelling land-use change to improve water quality in England. RSPB/WWF/Water UK. To receive a copy of the full project report, or further copies of this summary, please contact Jim Densham at the RSPB, jim.densham@rspb.org.uk or download from www.rspb.org.uk/waterwetlands/lawandpolicy/diffusepollution.asp

Acknowledgements

The authors would like to acknowledge the substantial contribution of the ADAS Catchment Management team, in particular Mark Shepherd, without whom the report would not have been written; the support and advice of members of the Technical Steering Group, in particular Hannah Bartram, Penny Johnes, Robert Oates and Jacob Tompkins; the additional helpful advice of Sue Armstrong-Brown, Louise Heathwaite, Liane Jarman, Tom Le Quesne, Ken Smith and Gwyn Williams.

Cover photograph by Andy Hay (rspb-images.com)

Contents

Executive summary

- Nutrient pollution of water damages ecosystems and costs water customers money. The results of this project show that over half of England's rivers may be at risk of damage from phosphorus pollution.

- Discharges from sewage works are still a significant source of pollution in the water environment. In the six catchments modelled, the estimated contribution from sewage outfalls ranged from 9% to 60%.

- Common Agriculture Policy reform measures alone are unlikely to lead to a healthy water environment. However, good practice techniques and simple, low-cost agri-environment measures, combined with CAP reform, could make a real difference, but only if widely and consistently applied.

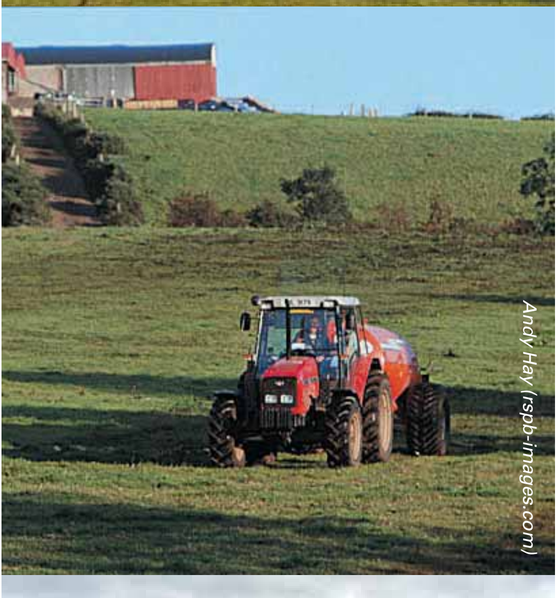
- The creation of more areas of wildlife habitat, combined with support for extensive and low-input farming, would have multiple benefits, and help achieve required water standards.

- In some areas, land-use change may be needed to tackle chronic pollution problems, or protect ecologically sensitive sites or drinking water sources. This could involve taking land out of intensive arable production or significant reductions in livestock numbers.

- The land use patterns identified by this project, which meet Water Framework Directive standards and biodiversity targets, will have major implications for agricultural systems, agri-environment resources, and advisory support. An important next step will be to develop understanding of ways to meet forthcoming water legislation and maximise other environmental benefits for wildlife and landscape, whilst ensuring that farm businesses can adapt and remain profitable.

David Broadbent (rspb-images.com)


David Kjaer (rspb-images.com)


Andy Hay (rspb-images.com)


WWF-UK

Poor management of animal manure and slurry can increase the risk of nutrients entering watercourses in runoff

1 Introduction

Water, agriculture and nutrients

Farming covers over 70% of the land of the UK. As well as providing us with food, farmers maintain landscapes and wildlife, and support the life and livelihoods of thousands of people in rural communities.

But, agricultural activity can also damage the environment. Where soils are poorly managed, and where manure, fertilisers or pesticides are applied inefficiently or at the wrong time, this can affect the quality of water reaching our rivers, lakes and seas.

One of the most serious problems facing the water environment is pollution by plant nutrients – in particular, nitrogen and phosphorus. These substances are essential for plant growth; but too much of them in the wrong place can lead to a phenomenon known as eutrophication. Eutrophication – literally the over-feeding of ecosystems – results in oxygen depletion, changes in water chemistry, food-chain imbalances, increases in toxic algal blooms and the collapse of populations of sensitive species. The Millennium Ecosystem Assessment, a United Nations project using data from natural science groups around the world identified eutrophication as one of the three most serious threats to biodiversity and ecosystem function, alongside climate change and habitat loss.

Eutrophication is threatening some of England's most precious wildlife. English Nature, the Government's nature conservation advisors, reported in 2005 that over 100 of England's most sensitive wildlife sites have been damaged by diffuse pollution. Many species are also at risk, including plants like the water violet, birds like the bittern, and valuable fish stocks of salmon and trout. Pollution by nutrients also affects drinking water, leading to increasing treatment costs for water companies and their customers. It is estimated that the current costs of aquatic eutrophication in England and Wales are in the order of £250 million per year.

How do nitrogen and phosphorus enter water?

Plant nutrients can reach water from many sources, but the most important of these are sewage outflows and run-off from farmland.

Phosphorus and nitrogen enter the agriculture system in the UK in the form of inorganic fertilisers and, in particular phosphorus, within livestock feed. Nitrogen is susceptible to leaching from soils where it can enter groundwater and surface waters whereas phosphorus generally binds to soil and enters water when soils are eroded. Both nitrogen and phosphorus can be recycled to fertilise plants through animal manure and slurry but poor management of these organic materials can increase the risk of them entering watercourses in runoff.

The proportion that comes from agriculture is increasing, as higher standards of water treatment reduce the contribution from human waste. In 2002, it was estimated that agriculture was responsible for around half of the phosphorus entering water in England, and 70% of the nitrogen. The focus of this report is agricultural diffuse pollution; however, it is important to acknowledge further action will be needed to clean up sewage discharges too, if we are to improve the health of our waters.

What action is being taken to tackle the problem?

The UK Government recognises the need to address diffuse agricultural pollution, and included a pledge to do so in its 2005 General Election Manifesto. Action is needed now, if the UK is to protect and restore aquatic and wetland wildlife, and protect water customers from further costs. The UK also needs to act, if it is to meet new standards for water quality laid down in the European Water Framework Directive, a new law covering all the surface and ground waters of the EU; and to meet existing obligations under the Nitrates, Bathing Water, Birds and Habitats Directives, and under the Countryside and Rights of Way Act.

The Government is at present working on plans to promote catchment sensitive farming and achieve better water quality. We already have a good understanding of the kinds of practical measures that could help. We are less certain, however, about how much action is needed in different areas; and how recent reforms to the Common Agricultural Policy might contribute to solving the problem. The project described in this report was designed to improve our understanding of these issues and hope that it will support the Government in making appropriate choices for the management of this challenging and important environmental problem.

Better land for better water: scenarios for change

This report summarises the results of an 18-month project, jointly funded by the RSPB, Water UK and WWF, and developed with technical support from ADAS. The project's aim was to explore the changes in farmed land-use and management that might be necessary to achieve nutrient levels in rivers compatible with healthy aquatic ecosystems. Because phosphorus is generally considered to be the limiting nutrient in freshwaters, and therefore has the most potential for environmental impacts if levels are increased, this is the main focus of the report. The full technical report, from which this summary is derived, is available online at www.rspb.org.uk/waterwetlands or from the project partners.

David Kjaer (rspb-images.com)

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Andy Hay (rspb-images.com)

Eutrophication is threatening some of England's most precious wildlife

2 The catchment approach

What is a catchment?

A catchment or watershed is the area of land from which water drains into a river, lake or estuary. How this land is managed affects both the quality and quantity of water reaching water bodies. Because of this, catchments are often thought of as the natural units of water management.

To manage catchments effectively, we need to understand the links between water quality and geology, hydrology, climate and land use. One way to do this is by using catchment-scale models. These build a 'picture' of a catchment, allowing researchers to manipulate different factors, to explore the effects on water quality. This project employed a catchment-scale model to predict the effects of changes in agricultural land-use and management on loads of phosphorus reaching the water.

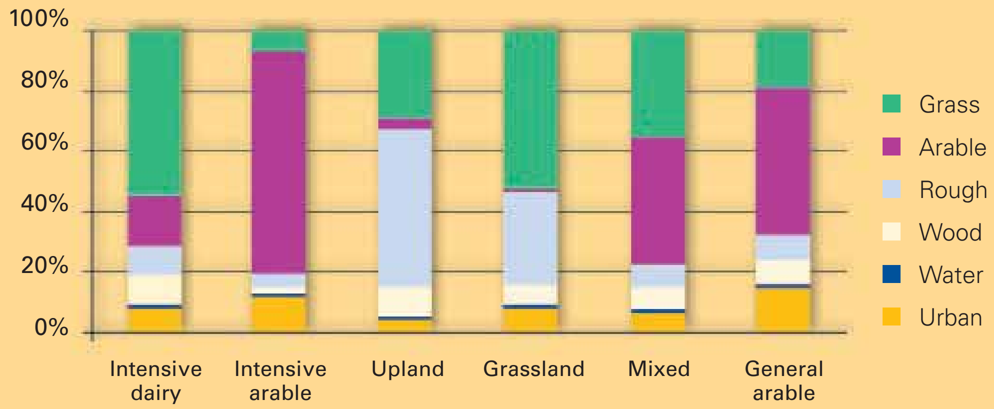
Sample catchments

The project modelled the effects of land use and management changes in six representative sample catchments. These catchments, described below, although real, were chosen to represent different climates, soils and land-uses within England.

Table 1
Details of the six sample catchments

Catchment	Location	Geology and climate	Predominant land-use
A	SW England	Average annual rainfall 1000 mm, greensand and clay grading into alluvium and valley gravels	Dairy and sheep farming, some beef
B	E England	Average annual rainfall 580 mm, light soils	Intensive arable farming with pigs as the major livestock
C	NE England, uplands	Average annual rainfall 855 mm, carboniferous limestone and millstone grit	Sheep farming dominant, large areas of Site of Special Scientific Interest
D	NW England	Carboniferous limestone, millstone grit, boulder clay over coal measures	Improved grasslands, dairy and sheep
E	SW England	Average annual rainfall 750 mm, oolitic limestones with tributaries draining off clays	Mixed farming with a proportion of field vegetables
F	S England	Average annual rainfall 750 mm, weald clay, with chalk predominating in some areas	Arable dominant but urban land-uses occupy as much as 15%

Figure 1
Land-use in the sample catchments



3 Water quality: what are we aiming for?

Water quality can be measured in many different ways. In England, data is collected on the concentration of specific chemicals, on water levels and flows, and on the presence, absence or abundance of particular organisms.

However, scientists have recognised recently that the ecological health of water – its ability to support characteristic plants and animals – is a vital measure of its quality. This principle is enshrined in a new European law called the Water Framework Directive (WFD), which promotes the sustainable management of water across Europe.

This project aimed to understand how agriculture might need to change, to achieve phosphorus levels compatible with healthy ecosystems and new standards under the WFD. The relationship between phosphorus levels and river life is complex, and it was decided that for this project, threshold values already established by the Environment Agency for implementing the Water Framework Directive would be used, see table 2. The values chosen are specific to different river types, depending upon size and geology. They reflect current Agency thinking, and so are an appropriate benchmark for Good Ecological Status, the central standard of the WFD. It is recognised, however, that they may need to be adapted in the future, as understanding of aquatic ecology grows.


Andy Hay (rspb-images.com)

Table 2
Type-specific P values for river types, used as a proxy for Good Ecological Status (source: Environment Agency)

	Productivity low (organic/ siliceous)	Threshold confidence	Productivity moderate/high (calcareous)	Threshold confidence
Not at risk	<0.02	high	<0.06	medium
Probably at risk	0.02–0.04	medium	0.06–0.1	medium
At risk	>0.04	high	>0.1	medium

Appropriate threshold values for phosphorus have been chosen by the Environment Agency to indicate risks to Good Ecological Status of water


Gwyn Williams/RSPB

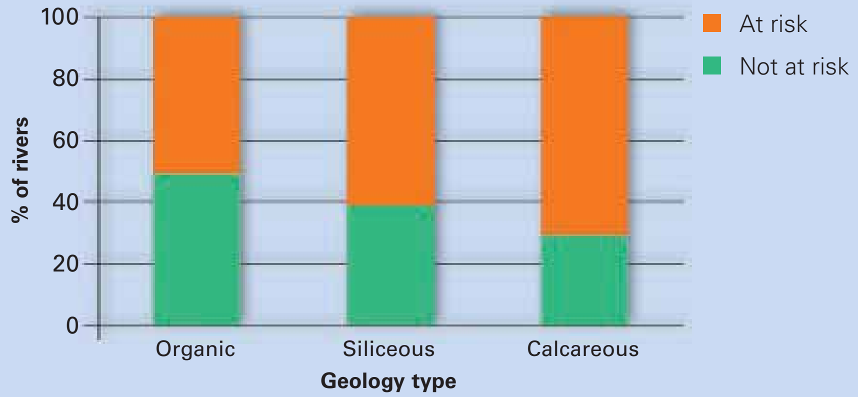
4 How big is the nutrient problem?

The problem in England and its sources

The project compared existing phosphorus levels in rivers in England with the ecologically relevant threshold values, developed to help implement the Water Framework Directive. The results indicate that between 51% and 71% of rivers in catchments are at risk of ecological impacts from phosphorus, depending on the underlying geology of those catchments.

Concentrations of phosphorus in rivers are the result of 'point' source discharges, such as sewage outflows, and diffuse sources such as farmland and roads. The project assessed 688 river stretches, looking at phosphorus concentrations before and after the point of a discharge by a sewage treatment works. More than 60% of stretches showed significant point source influences. This is despite phosphorus treatment plants being added to many sewage treatment works.

Figure 2
Percentage of rivers of three dominant geology types at risk of not achieving ecologically relevant standards of phosphorus



Paul Glendell/Still Pictures

WWF-UK

Phosphorus from sewage and agricultural runoff is putting over half of England's rivers at risk of ecological impact

The problem and its sources in sample catchments

As well as analysing national data about nutrients in rivers, the study looked in more detail at the levels and sources of phosphorus in our sample catchments. Data on human population numbers was used to work out how much of the phosphorus reaching water comes from sewage, rather than diffuse sources. The reduction in agricultural phosphorus export needed, to achieve our target threshold levels was then calculated. In each case, it was assumed that the reduction in phosphorus loss from agriculture required was proportionate to its contribution to the overall load; and that a similar, proportional reduction would be required from point sources.

The results from the project's catchment analysis show that phosphorus levels vary substantially between catchments. Upland areas tend to have lower levels of phosphorus than lowland areas, and areas with low rainfall tend to have higher concentrations because of the limited potential for dilution. The scale of change required to achieve our WFD-relevant standard varied similarly, with the greatest challenges in areas with large numbers of livestock or with low annual rainfall.

Figure 3
Pollution sources contributing to total P export under baseline calculation

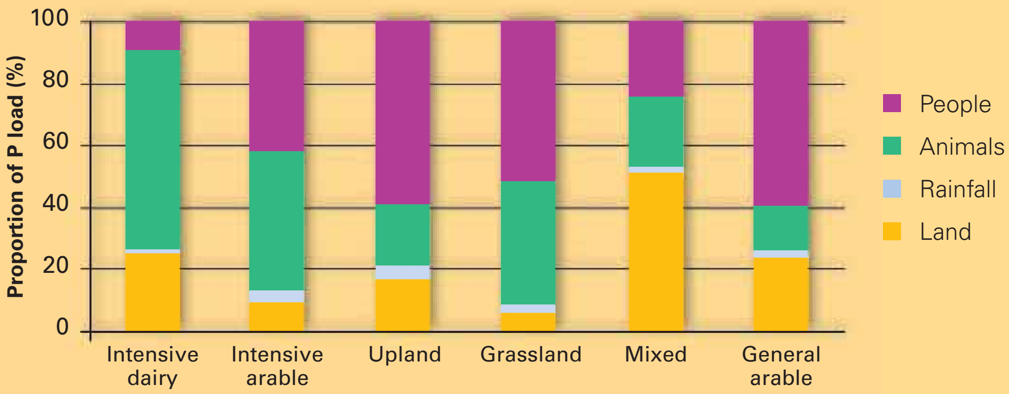
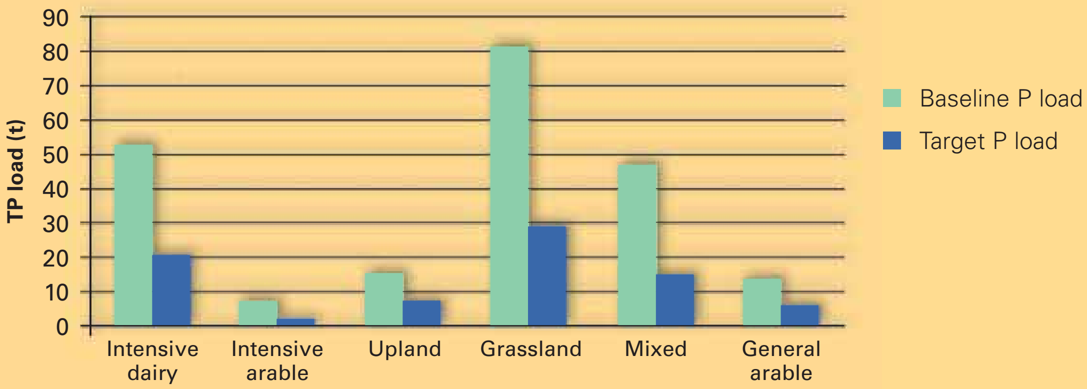


Figure 4
Baseline agricultural phosphorus load and targets reductions required from agricultural activities



5 Scenarios for change

The project developed catchment-specific scenarios to test the impacts of different farm practices and patterns of land-use on phosphorus loads to rivers. In each case, the results are recorded as the percentage of the target reduction achieved.

Scenario 1: Good Agriculture Practice (GAP)

This scenario was designed to assess the effects of changing farm practice *within* existing land-uses. A review of previous research was used to estimate the level of nutrient reduction that might be achieved using a range of good practice measures. These included improved soil management, more targeted manure and fertiliser application and pollution mitigation measures. Two variants of the GAP scenario were tested, based on their potential cost for farm businesses.

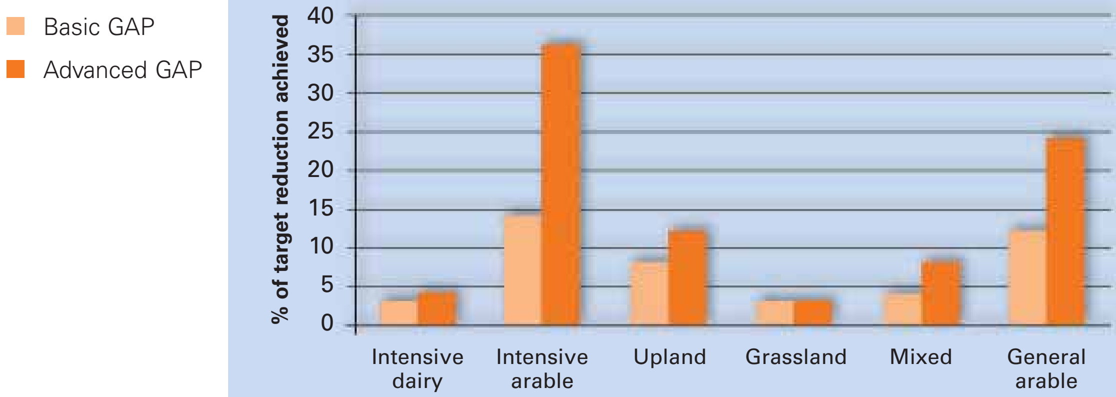
Scenario 1a: Basic GAP – Low cost/no cost measures, some of which could reduce costs to farm businesses.

Scenario 1b: Advanced GAP – Measures under Basic GAP, plus measures that would incur more substantial costs to the farm (including capital investment).

Results: With basic GAP, between 3% and 14% of the required reductions were achieved, and with advanced GAP, between 3% and 36%. Application of GAP was generally more effective in arable than in grassland catchments.

Implications: Significant reductions in agricultural phosphorus export can be achieved by the use of low cost management measures, particularly in areas dominated by arable land-uses. However, these will not be enough on their own to achieve ecologically healthy, threshold levels of phosphorus in rivers.

Figure 5
Percentage of target reduction with Good Agricultural Practice



Scenario 2:
Business As Usual (BAU) land-use forecast

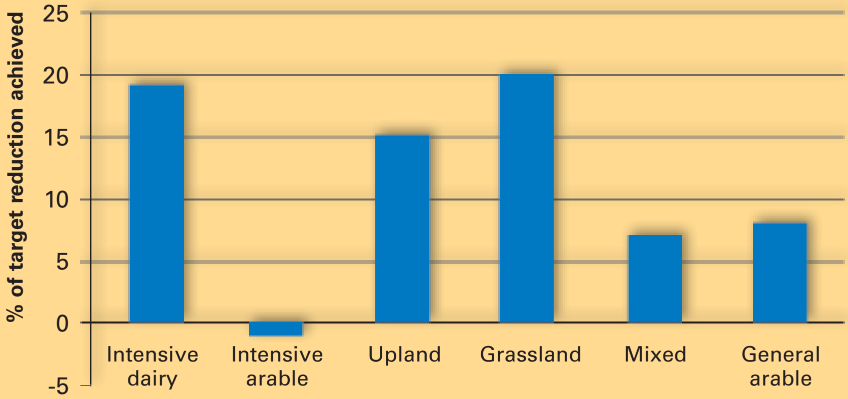
This scenario modelled the changes in land-use following the implementation of Common Agricultural Policy reforms, predicted by a Cambridge University project for Defra. The most significant predicted changes by 2015 were reductions in livestock numbers, intensification of remaining livestock enterprises, and some increases in arable and farm woodlands. Analysis of regional variation was used to develop an appropriate scenario for each of the six project catchments.

Results: The contribution to the targeted level of reduction was as much as 20% in the grassland and upland catchments, but negative in the intensive arable catchment.

Implications: Under the Business As Usual scenario, some substantial reductions to phosphorus loads can be expected in some areas but, in others, the contribution will be very small, and in arable areas the effect may even be negative. Further action will be required to meet standards relevant to WFD.

CAP reform measures alone are unlikely to be enough to restore a healthy water environment

Figure 6
Contribution to target reduction under the Business As Usual scenario



Targeting agri-environment measures to the right places is likely to make them more effective in reducing the amount of phosphorus entering water

Scenario 3: Agri-environment Measures

Scenario 3 applied options available under the Environmental Stewardship scheme in England (ELS and HLS), with the aim of understanding how agri-environment support would contribute to reductions in phosphorus loads, if funding was unconstrained.

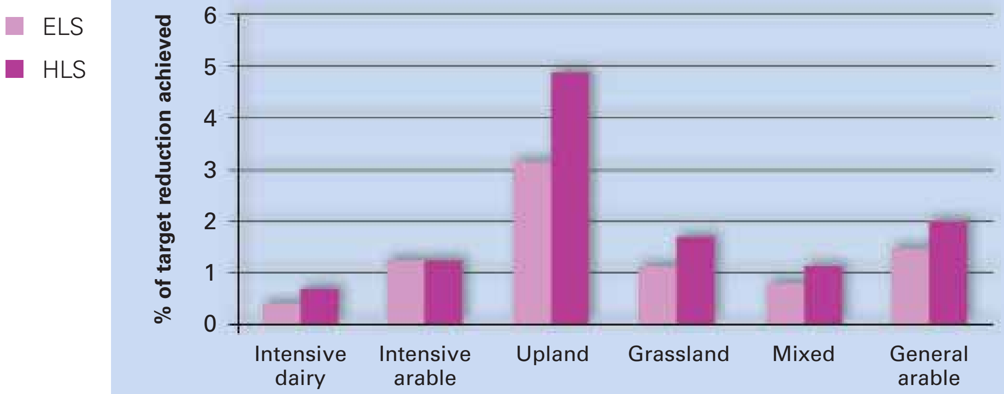
Scenario 3a studied the effect of selected ELS options including soil management, livestock reduction and input reduction measures. The estimated uptake of options in the sample catchments was based on data from the ELS pilot areas.

Scenario 3b attempted to model the effect of HLS options on nutrient export. Since the options for HLS were not finalised at the time of the study, in order to predict uptake the options were compared to uptake of similar options under the Countryside Stewardship Scheme. The options modelled included semi-natural habitat creation options (for example, fens and reedbeds), arable reversion to grassland, and restoration of low-fertility grasslands.

Results: ELS and HLS gave results in the order of 1–5% contribution towards target reduction. These relatively small contributions probably reflect the limited predicted uptake of measures, combined with the challenge of accurately modelling subtle changes likely to be brought about by ELS/HLS, rather than the quality of the options themselves.

Implications: To be effective, it is likely that agri-environment measures would need to be taken up over large areas and be strategically located in the catchment. Doubts exist as to whether funding and expert advice are currently available to achieve this adequately in all English catchments notwithstanding the funding allocated by Defra to 40 catchments under the England Catchment Sensitive Farming Delivery Initiative.

Figure 7
Percentage contribution to target P reduction with ELS and HLS

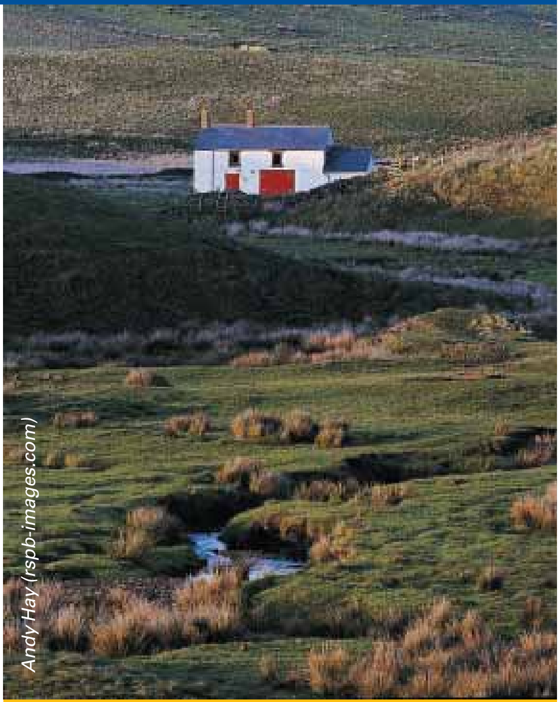


Scenario 3c: BAU + ELS + Advanced GAP

Scenario 3c combined the results of modelling BAU, Advanced GAP and ELS. By modelling these measures together, the project estimated the maximum reductions that might be achieved, from the expansion and enhancement of current policy instruments. This scenario is based on universal application of good practice measures, and the widespread adoption of basic agri-environment measures, overlying CAP reform impacts.

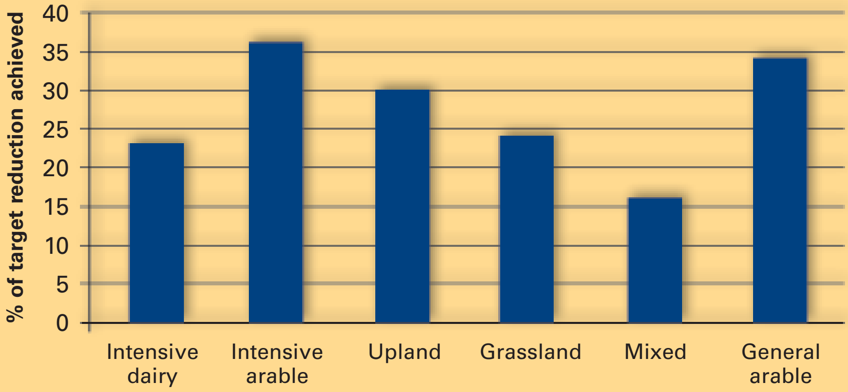
Results: The scenario predicted in the order of a 30–35% P reduction against target in the upland and arable catchments. Measures were less effective in lowland catchments with livestock.

Implications: Widespread and effective application of improved agricultural practice, combined with good uptake of Entry Level agri-environment measures could have a substantial impact on pollution by phosphorus. Further action will still be required, however, to meet ecological water standards in many areas, particularly in areas dominated by intensive livestock farming.


Andy Hay (rspb-images.com)

A combination of low-cost measures could make a real difference in upland catchments

Figure 8
Percentage of contribution to target P reduction with BAU + ELS + Advanced GAP



The creation of more semi-natural habitat would help achieve better water quality

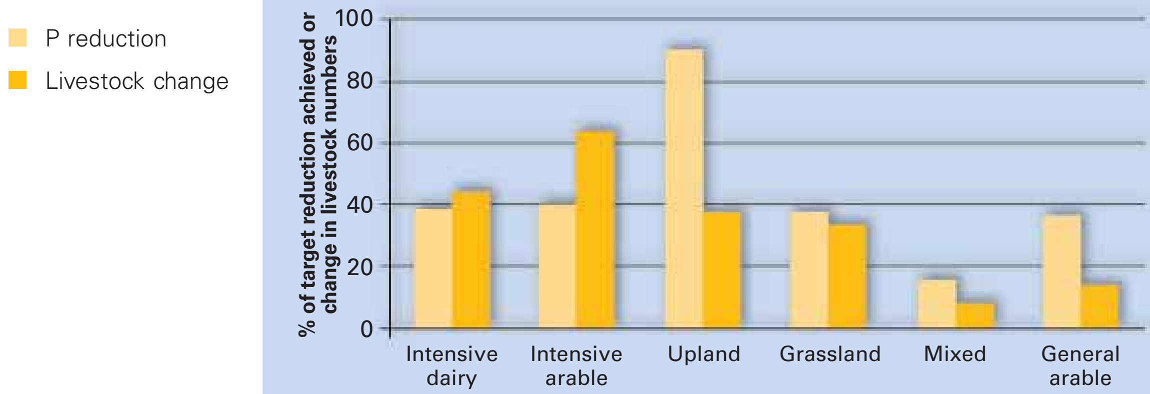
Scenario 4: Wildlife-Rich Landscape with GAP

Farmed landscapes provide important habitats for species such as skylark, corn bunting and black grouse. However, the delivery of Government Biodiversity Action Plan targets will also require the re-creation of much larger areas of habitats such as heathland, wetlands and woodland. The Wildlife-Rich Landscape (WRL) scenarios were designed to deliver landscape-scale benefits for biodiversity and developed with input from local conservation staff, referencing Local Biodiversity Action Plans. Basic GAP outcomes, from Scenario 1, were incorporated into the design. In general, this scenario was characterised by more mixed farming, decreased inputs, extensification of livestock enterprises and a greater area and variety of semi-natural habitats.

Results: Significant reductions in agricultural P loss were achieved. Even so, the results suggest that a WFD-compliant result could only be realised in the upland catchment, with other catchments reaching about 40% of the target reduction.

Implications: The creation of more semi-natural habitats to support wildlife, and a shift to more extensive and mixed farmed businesses, would make a substantial contribution to meeting targets. However, in some areas this alone would not be sufficient to achieve ecologically healthy levels of phosphorus in rivers. No economic assessment of this scenario was included, but it is acknowledged that this scenario assumes substantial changes to the level of farming activity in some parts of the catchments and would require significant public support.

Figure 9
Contribution to target P reduction with the WRL scenario. Graph also shows the reduction in livestock numbers associated with the scenario



Scenario 5: Radical Change

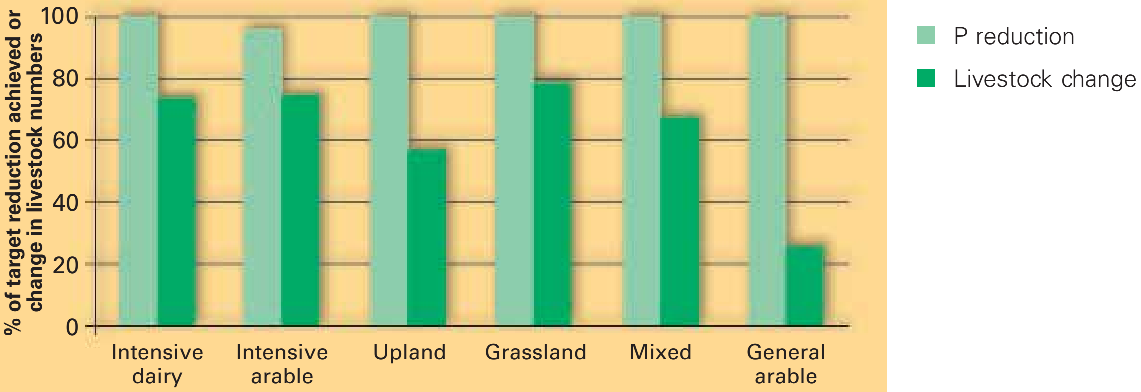
The aim of the Radical Change scenario was to alter land uses to achieve our phosphorus targets in each catchment. The scenario was developed by building on changes modelled in the WRL scenario, and considered phosphorus reductions from all agricultural sectors. For each catchment, phosphorus reductions were achieved through land use changes such as increases in rough grazing, reductions in livestock numbers and reduced fertiliser and manure inputs.

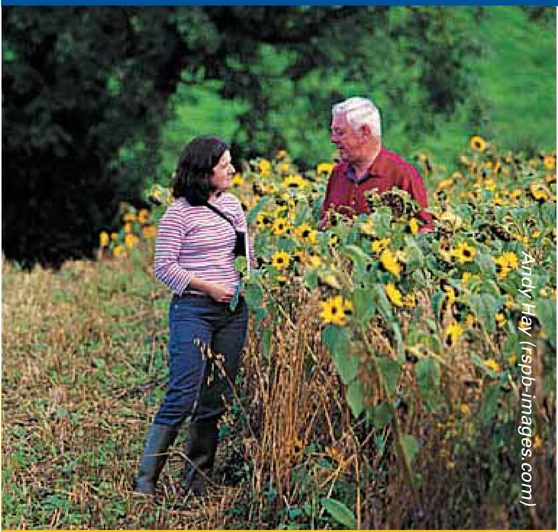
Results: Five catchments achieved 100% of the targeted reduction. Significant changes in livestock numbers were required to bring this about. The intensive arable catchment achieved significant reductions, but failed to reach the target, reflecting the difficulty of controlling phosphorus concentrations in areas with low rainfall.

Implications: In some cases, radical changes to land use may be needed, to protect drinking water sources or ecologically sensitive sites, and as required by the Water Framework Directive. Policy, advisory and funding drivers are not currently geared to deliver change on this scale, and the consequences for farming and the rural economy must be considered. Even with such changes, there may be areas where it is difficult to achieve target levels of phosphorus, particularly where climate change further reduces summer rainfall levels.

In some areas, land-use change may be needed to protect drinking water sources and/or ecologically sensitive sites

Figure 10
Contribution to target P reduction with Radical Change. Graph also shows the reduction in livestock numbers associated with the scenario





The land-use patterns identified by this project will have major implications for agricultural systems, agri-environment resources and advisory support

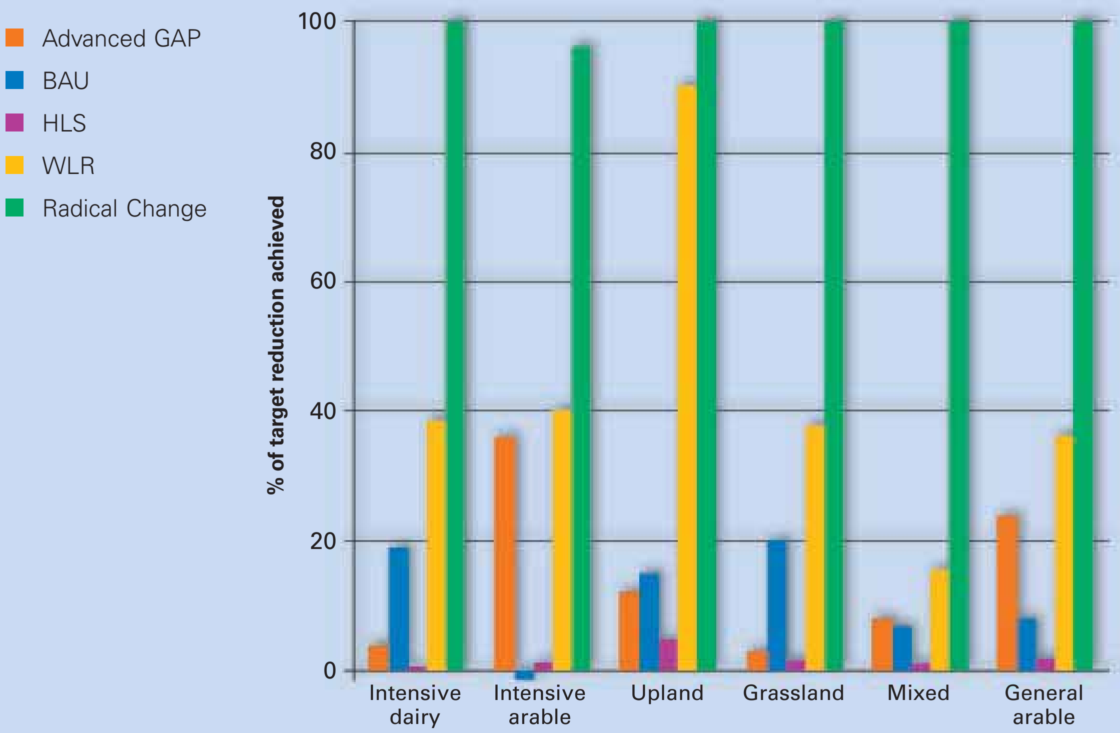
6 Conclusions

Water pollution by phosphorus is a serious problem, with costs for wildlife and water customers. Action is needed now to tackle phosphorus discharges from sewage effluent, and to reduce agricultural phosphorus reaching UK rivers.

On the basis of modelling phosphorus losses from six representative catchments with contrasting land-use patterns, adoption of best practice and the changes in land use expected to result from CAP reform will have benefits for reducing diffuse pollution from agricultural land. However, these alone will not be sufficient to meet Water Framework Directive standards. Further measures will be needed to address chronic problems, protect ecologically sensitive sites and drinking water sources. These include the uptake of good practice measures on all farms, the creation of more areas of semi-natural habitat and, in some cases, more radical land-use change.

The land use patterns identified by this project, which meet WFD standards and biodiversity targets, will have major implications for agricultural systems, agri-environment resources, and advisory support. An important next step will be to develop understanding of ways to meet forthcoming water legislation and maximise other environmental benefits for wildlife and landscape, whilst ensuring that farm businesses can adapt and remain profitable.

Figure 11
Summary of scenario results



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This report is part of WWF–UK's Natural Rivers Programme, which is supported by HSBC. The programme is developing innovative techniques for the management and restoration of rivers and wetlands for the benefit of people and nature.

WATER UK

Water UK is the association of water service companies. On behalf of its members and their customers it promotes research and debate on land management and protection of the water environment.

Technical reviewer

ADAS

ADAS is a specialist research and consultancy company, covering a wide range of environmental issues. We understand the science of land and water interaction, and are committed to applying science to improve water quality and management.

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