Spatial Targeting of agri-environment measures for mitigating diffuse water pollution: report of a workshop held on 16\textsuperscript{th} July 2013

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Centre for Ecology and Hydrology
October 2013
1. Introduction

The spatial targeting of agri-environment measures for mitigating diffuse water pollution is vital for delivering improvements to water quality and for increasing the cost-effectiveness of agri-environment schemes. Spatial targeting is relevant at three different scales of interest. Nationally, there is need to prioritise areas by screening for those areas where diffuse agricultural inputs are the dominant cause of water pollution and where mitigation measures have the potential to bridge the gap between present and target values. At the catchment scale, there is a need to identify pollutant hotspots and connectivity in the context of pollutant sources and pathways so that appropriate mitigation measures can be developed and focused to tackle the main issues, thus yielding maximum benefit. Finally, measures need to be implemented at the farm scale through provision of advice to farmers and working in partnership. This requires knowledge on a field by field basis, understanding of what measures are appropriate and where they fit into both the landscape and the farm infrastructure. Connecting these scales and delivering effective improvements to water quality and to ecological status remains a challenge.

One important step in addressing this issue is to synthesise the relevant evidence, models, tools and approaches. To this end, a workshop was held on 16th July 2013 at the Centre for Ecology and Hydrology which brought together policy makers, WFD co-deliverers, researchers and practitioners to consider how to take this forward. The workshop was designed specifically to provide an overview of the feasibility of improving the performance of agri-environment schemes in addressing diffuse water pollution by spatially targeting measures at national, catchment and farm scales. In order to showcase as many targeting methodologies as possible, the approach was through short presentations and accompanying posters/demonstrations giving further details. The programme and list of attendees are given in Appendix I.

This technical report describes the current state of the art of tools and methods, applicable at different scales, for spatial targeting of agri-environment schemes for agricultural diffuse pollution mitigation. It presents (i) the policy and operational context for spatial targeting, including recent initiatives being undertaken by Defra, Natural England and the Environment Agency; (ii) a compendium of the datasets, modelled GIS layers, methodologies and tools presented at the workshop; and (iii) a synthesis of discussion points and recommendations for taking these forward. It is planned that the results of the workshop will also be distilled into a short policy statement.

2. Context

The workshop was set within the context of a need to improve the implementation of the EU Water Framework Directive in England with respect to agriculture. Rather than the current broad universal approach embedded within agri-environment schemes, the aim would be to make mitigation measures which specifically address the issue of improving water quality, and the proper targeting of those measures, a priority for funding. To make progress on this initiative, there are three underlying issues:

- identifying the gaps in policy and the framework for delivery
Identifying basic measures i.e. simple actions applicable to all farmers to ensure compliance with regulations e.g. CAP Pillar 1 “greening measures”

Identifying supplementary targeting measures to help to deliver water quality improvements.

There are a number of current initiatives by Defra, the Environment Agency and Natural England which relate to these questions:

- Natural England are leading work on a New Environmental Land Management Scheme (NELMS). The effectiveness (advantages/disadvantages) of options and capital items within Environmental Stewardship (ES) and Catchment Sensitive Farming (CSF) capital grants have been reviewed and draft proposals for new scheme options are imminent.

- The Environment Agency is undertaking economic appraisal of measures to achieve good ecological status in the second cycle of basin management planning by 2021 as required by the WFD. The timetable for this is April 2014 for draft and August 2015 for second cycle River Basin Management Plans.

- Defra have launched a Catchment Partnership Fund, administered by the Environment Agency, to support the establishment of partnerships amongst local stakeholders within water management catchments in England in order to identify issues (both agriculture and urban) and to encourage collaborative working and a greater commitment to action.

- Defra has commissioned Natural England and the Environment Agency to identify ways of achieving more integrated delivery of the Biodiversity 2020, Water Framework Directive, and Flood and Coastal Risk Management Programmes. Preliminary findings of The Synergies Project have highlighted, amongst other things, the need for improved design and targeted location of measures for successful multiple-objective working including the need to identify packages of measures and priority deployment areas – both at the scale of bio-geographical areas and spatial hotspots. Alongside this, the development of tools for improving farm-scale targeting of measures and of the evidence base to improve choice and location of measures have also been highlighted.

In terms of practical delivery of effectively targeted agri-environment measures at the farm scale, key points, from the experience of a farm adviser were:

- Information must be translated to the farm scale to be meaningful. Both advisors and farmers need publically available data providing targeted and accessible information.

- Advice is necessary, otherwise delivery is random. In the entry-level stewardship scheme, there has been no/little advice mediation, therefore, farmers select options they likes and place them on the farm in areas to suit them. Sometimes, they are perfectly placed for resource protection but not necessarily by design. The farmer may
not know where best to place options for resource protection so advice should make a difference in terms of delivering improvements.

- Knowledge and interests of advisors shape what the scheme delivers so advisors need to be trained in all objectives (resource protection and biodiversity). Only about 25% advisors have soil and water training.

- Small grants are very effective for encouraging change as they provide motivation and farmers feel they are being helped. Advice on problem areas is also valuable.

3. Methodologies, Tools, GIS layers and Datasets

Based on the workshop presentations and information provided by the developers of methods, tools, GIS layers and datasets, Appendix II provides a compendium of approaches to spatial targeting at national, catchment and farm scales. Where possible, information has been collated to provide a basic description, relevance to spatial targeting, background, scale and data requirements, applicability, known limitations, availability, expertise needed, example applications, contact details and references. The entries have been grouped in terms of tools/models and data/survey methods and Table 1 gives a summary overview.
## Table 1 Summary overview of methodologies, tools, GIS layers and datasets

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Use in spatial targeting</th>
<th>Contact</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASPIRE</td>
<td>tool</td>
<td>National and catchment scale; contribution of agricultural diffuse pollution to fine sediment; potential reduction by mitigation measures; biological impact (invertebrates and fish)</td>
<td>Adie Collins, Rothamsted Research-North Wyke</td>
</tr>
<tr>
<td>SAGIS</td>
<td>tool</td>
<td>National and catchment scale; cross-sector source apportionment including nutrients, metals and organics.</td>
<td>Carlos Constantino, Atkins</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Peter Daldorph, Atkins</td>
</tr>
<tr>
<td>EVOp</td>
<td>tool</td>
<td>National scale; biogeochemical modelling framework supported by cloud computing infrastructure; export coefficient model for TN and TP set up for nine geoclimatic regions</td>
<td>Penny Johnes, Reading University</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sheila Greene, CEH</td>
</tr>
<tr>
<td>Scimap</td>
<td>tool</td>
<td>Catchment to farm scale; identification of areas most likely to be responsible for diffuse pollution in terms of source and connectivity</td>
<td>Sim Reaney, Durham University</td>
</tr>
<tr>
<td></td>
<td>application</td>
<td>Catchment to farm scale; inclusion of drainage ditches in SCIMAP</td>
<td>Haydn Probert, Wye and Usk Foundation</td>
</tr>
<tr>
<td>PEDAL</td>
<td>tool</td>
<td>Catchment to farm scale; effect of placement of mitigation measures (buffer strips and wetlands) on phosphorus loss</td>
<td>Louise Heathwaite, Lancaster Env. Centre</td>
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<td></td>
<td></td>
<td></td>
<td>David Oliver, Stirling University</td>
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<td></td>
<td></td>
<td></td>
<td>Ting Zhang, CEH</td>
</tr>
<tr>
<td>ECM+</td>
<td>tool</td>
<td>Catchment to farm scale; export coefficient cross-sector model for SRP, DIN, sediment and FIOs including uncertainty; ability to run good/bad farm scenarios and effect of uptake of measures</td>
<td>Nick Paling, Westcountry Rivers Trust</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Tobi Kruger, Humboldt University, Berlin</td>
</tr>
<tr>
<td>FIOs</td>
<td>tool/data</td>
<td>Catchment scale; export coefficient model for FIOs for screening/defining hotspots; collation of field data for effectiveness of measures for FIOs</td>
<td>David Kay, Aberystwyth University</td>
</tr>
<tr>
<td>Fieldmouse</td>
<td>tool</td>
<td>Catchment/farm scale; identifies holdings that contribute most to river loading; holdings that will respond best to intervention measures; optimisation of packages of measures</td>
<td>John Douglass, EA</td>
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<td></td>
<td></td>
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<td>Linda Pope, EA</td>
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<td></td>
<td></td>
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<td>Barry Hankin, JBA Consulting</td>
</tr>
<tr>
<td>Empirical LAM</td>
<td>tool</td>
<td>Catchment scale; load apportionment based on relationships between nutrient concentration and flow to differentiate constant from rainfall-related sources; applicable to algal impacts</td>
<td>Mike Bowes, CEH</td>
</tr>
<tr>
<td>WQ0223</td>
<td>GIS layers</td>
<td>National scale for screening purposes; nutrient and fine sediment relating to ecological windows; potential reductions due to mitigation measures; mapping of groundwater nitrate and lake sediment phosphorus legacy issues; hydromorphological constraints</td>
<td>Pam Naden, CEH</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Adie Collins, Rothamsted Research-North Wyke</td>
</tr>
<tr>
<td>Freshwater ecological metrics</td>
<td>data analysis</td>
<td>National to local scales; point measurements across UK; identification of stressors; can be linked to tools (e.g. ASPIRE)</td>
<td>Iwan Jones, QMUL</td>
</tr>
<tr>
<td>Remote sensing tools</td>
<td>data</td>
<td>Catchment to farm scale; multiple data products from remote sensing for targeting catchment walkovers; data also potentially useful in other models</td>
<td>Crispin Hambidge, EA</td>
</tr>
<tr>
<td></td>
<td>tool/data</td>
<td></td>
<td>Andrew Richman, EA</td>
</tr>
<tr>
<td>3D visualisation</td>
<td>tool for data</td>
<td>Catchment to farm scale; conversion tools from GIS into 3D landscape visualisation</td>
<td>Andrew Lovett, UEA</td>
</tr>
<tr>
<td>Ground survey methods</td>
<td>survey methods</td>
<td>Farm to catchment scale; specialist walkover surveys to identify priority sources, verify their contribution and work with farmers to develop plans for implementing mitigation measures</td>
<td>Peter Dennis, APEM</td>
</tr>
<tr>
<td>Soil erosion dataset</td>
<td>field data</td>
<td>Farm scale; dataset describing soil erosion for 17 localities across England and Wales (1700 fields 1982-1986)</td>
<td>Bob Evans, Anglia Ruskin University</td>
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</tbody>
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4. Discussion

This Section reports the ensuing discussion which focused on four main themes: knowledge exchange, diffuse water pollution in a wider context (including links with biodiversity), critique of models, and data sharing and standardisation.

A. Knowledge Exchange

There is a fundamental need to improve knowledge exchange in order to move from basic research to outputs that are tailored to answering policy questions or to operational practice. Essential to this, is better definition of the objectives and needs of policy and operational practice. The challenge then is how to consolidate the approaches and tools that are already available into something more usable.

There is a need for modellers and the end-users of their models to work together better as a community. This should enable (i) a more effective iterative process between developers of tools and policy-makers or practitioners regarding the tailoring of tools, (ii) better knowledge and sharing of existing data (e.g. APEM conducted a walkover survey of the Wensum three years ago, Bob Evans has also walked the Wensum in relation to sediment risk and yet these datasets are not linked in with the DTC work) and (iii) making tools available for catchment managers, policy makers and other decision makers to use.

To support knowledge exchange, an ongoing dialogue is needed. This could, for example, be fostered through an online forum, hosted by Defra, through which policy questions can be posed to an academic audience with the aim of developing a stronger link between policy and academia.

B. Diffuse water pollution in wider context (including links with biodiversity)

The framework for mitigating diffuse water pollution needs to be wider than water quality – embracing flood risk, water resources (including groundwater) and climate change. In order to make progress on water quality targets, we need a good assessment at the catchment scale of source apportionment and the scale of measures necessary to achieve improvements. In-river sources, hydromorphology and other factors (e.g. signal crayfish activity) should not be ignored. Changes in the farming industry (e.g. reduction in phosphorus inputs due to increased fertiliser cost and a move to precision farming) also need to be factored into assessments of diffuse pollution mitigation.

In terms of targeting, it is important to compare on-farm measures with land-use change measures and the link between national and farm scales needs to be improved in response to multiple objectives. This requires improved coordination between policy interests. For example, there is a policy driver for increasing habitat but, to maximise ecological benefit, habitat needs to be joined-up rather than fragmented so there is a need to scope where such initiatives are acceptable in both policy and practice. The ecosystem mapping approach of The Rivers Trust might help to enable this in some degree but there needs to be more awareness of the approach, datasets and technology; the approach also needs extension in order to map onto nutrients and water quality aims.

The focus in the WFD is on improving the ecological status from bad/poor to good. However, the reality is one of multiple pressures rather than just water quality. It is yet unknown how
multiple stressors interact and how to prioritise different types of stressor and the integration of models/tools to deal with this. [One of the aims of Defra-funded project WQ0223 is to analyse ecological sensitivity in relation to multiple stressors and this analysis should improve evidence relating to this issue.] From a regulatory point of view, it would be ideal to know what can be achieved in terms of mitigation as, if efforts are spread too thinly, nothing will be achieved. Key to this is ecological monitoring and focusing on where there are impacts, rather than simply identifying high risk.

Research and ground survey has already identified key issues: small sewage works, tractor wheelings, runoff from farmyards. These should be priorities for mitigation. The results from the MOPS project regarding tractor wheelings is being taken forward but mitigation for this is hard to fund through agri-environment schemes; Defra/Natural England has a link project with SIMBA and Michelin relating to tramlines.

C. Critique of models

There are many models which appear to be doing similar things. This work needs consolidation and the development of a standardised tool kit which all (WFD co-deliverers, farm advisers etc) are happy to use c.f. standard methods for flood estimation.

Some models are freely available; for others, licensing is a barrier. In many cases, there is an expectation that models will be made available for use. However, an important step which is often missing is that (i) models need to be tailored to the requirements of decision makers and made fit-for-purpose and (ii) delivery staff need to be trained in interpreting and implementing model outcomes. These aspects are rarely funded.

In assembling a tool kit of models/approaches, there is a fundamental need for an honest description of what a model is good at, in terms of scale and the processes covered, and its short comings. There will not be one model as there are different landscape types e.g. TOPMODEL-based tools will not work in a flat landscape. Correct export coefficients should be used e.g. total phosphorus or soluble reactive phosphorus – their behaviour is different. Given this, there is a need for a critique of models to understand their differences and how they relate to ecological endpoints. Model outcomes are also dependent on the data used and, therefore, there needs to be a parallel exercise in describing available data and collating shared datasets. One possibility is to run all models/tools and approaches in one or more of the DTC catchments to test them (e.g. in the Tamar, SCIMAP, APEM walkovers, SAGIS, ECM+, FARMSCOPER and previously INCA are all being applied). Discussions on taking this forward are ongoing.

Models which look at the effect of mitigation measures are all dependent on the Measures Manual (Newell, et al., 2011) but this requires continuous updating with new evidence. It is essential that new information is captured and made accessible as soon as possible – perhaps a live system via a Wiki or web page would be suitable.

Most policy-support tools are aspatial; they provide coarse screening prior to a walk-over at farm level. At the farm scale, location is vitally important. Most models do not really address the detail at the farm scale e.g. linear structures such as drainage ditches, fields, hedges, tracks and, in many cases, land drainage are not included. There was some debate about developing very detailed farm-scale models e.g. drainage ditches can be added to SCIMAP (see above for application by Wye and Usk Foundation) and LIDAR data at 20 cm resolution
is becoming available. However, common sense and an ability to read the landscape is probably a more appropriate approach given that the “best solution is what a farmer lets you do”.

D. Data sharing and standardisation

There is a great deal of monitoring going on in Britain but there is a basic need for both data sharing and standardisation of methods of data collection. For example, citizen science currently has no agreed standards. Information relating to the implementation of mitigation measures also needs a standard way of reporting as many organisations, e.g. The Rivers Trust, UKWIR and Defra, want similar information. This should include uptake of measures, how and where they are applied. There is also need for agreement on what data should be collected so that the whole problem is covered, not just parts of it. Mapping approaches also need to be coordinated (e.g. to avoid parallel developments in EA, Natural England and The Rivers Trust). The value of past datasets was emphasised.

5. Recommendations

It was recommended that, in order to address the points raised in the discussion and to foster better and ongoing dialogue between policy-makers, operational practitioners (WFD co-deliverers, farm advisers) and researchers, two working groups be set up:

1. Working group on modelling tools focussed on
   (i) ways of communicating policy questions to an academic audience
   (ii) critique of models/tools (what they do best in terms of scale and processes; limitations both in terms of processes and landscape types)
   (iii) what needs to be done to tailor tools to meet policy and operational requirements
   (iv) identification of gaps in tool box

2. Working group on data focussed on
   (i) best way to update the measures manual, capturing new data and making it accessible
   (ii) standardisation of recording of measures, implementation and spatial location
   (iii) standards for data collection through citizen science

Reference

Acknowledgements
Funding of the workshop by Defra and the input from participants – both presenters and attendees – are gratefully acknowledged.
Appendix I  Programme and Attendees

SPATIAL TARGETING OF AGRI-ENVIRONMENT MEASURES FOR MITIGATING DIFFUSE WATER POLLUTION
Location: Centre for Ecology and Hydrology, Wallingford, Oxfordshire, OX10 8BB
Date: 16th July 2013

10:00 Introduction
Welcome by Professor Alan Jenkins, Director of Water and Pollution Science, CEH
Context: policy drivers, operational plans and timescales – Susie Willows and Dan McGonigle, Defra

10:10-11:10 National screening tools: identifying those WFD waterbodies where diffuse water pollution from agriculture is dominant (10 mins each) Chair: Kirsten Foot, Environment Agency
A new framework for targeting sediment mitigation options across England and Wales – Adie Collins, ADAS
The Source Apportionment GIS tool – Carlos Constantino and Peter Daldorph, Atkins
Use of freshwater ecological data and metrics in spatial targeting – Iwan Jones, QMUL
Enhanced national biogeochemical modelling capability through the EVOp portal: scenario testing of diffuse pollution mitigation measures from 1km² grid to national scale – Penny Johnes, Reading University and Sheila Greene, CEH
National-scale layers being developed within WQ0223 – Pam Naden, CEH

11:10-11:30 coffee

11:30-13:00 Catchment-scale characterisation: tools for identifying pollutant sources, hotspots, connectivity, pathways, site-specific source apportionment (10 mins each) Chair: Rachael Dils, Environment Agency
SCIMAP: diffuse pollution risk mapping – Sim Reaney, Durham University
Spatial targeting of mitigation measures for diffuse pollution in headwater catchments – Ting Zhang, Lancaster University
Faecal Indicator Organisms: a screening tool and spatial targeting of BMPs – Dave Kay, Aberystwyth University
Intelligent Catchment Planning – Nick Paling, Westcountry Rivers Trust
Diffuse pollution remote sensing tools – Andrew Richman and Crispin Hambidge, EA Geomatics
Nutrient load apportionment modelling – Mike Bowes, CEH
Catchment-scale characterisation using Fieldmouse – John Douglass, EA and Barry Hankin, JBA

13:00-14:20 lunch (including posters and demonstrations)

14:20-15:20 Local farm-scale targeting: working with farmers and on-farm constraints to place mitigation measures (10 mins each) Chair: Dan McGonigle, Defra
Lessons from on-farm delivery – Jane James, Heathside Consulting Ltd
Using Scimap to target in-field measures – Haydn Probert, Wye & Usk Foundation
Ground surveys to inform agri-environment measures for mitigating diffuse water pollution – Peter Dennis, APEM
Farm-scale targeting to combat soil erosion by water – Bob Evans, Anglia Ruskin University
3D visualisation tools – Andrew Lovett, University of East Anglia

15:20-17:00 Discussion: How feasible is targeting water quality mitigation in agri-environment scheme design and delivery?
tailoring options available within specific catchments; how much guidance do farmers need from advisors to get measures in the right places; how can we communicate targeting outcomes.
Workshop attendees

Jemilah Bailey         Defra
Jonathan Bowes        SEPA
Mike Bowes             Centre for Ecology and Hydrology
Chris Burgess          Environment Agency
Adie Collins           ADAS
Carlos Constantino    Atkins
Deborah Coughlin       Defra
Peter Daldorph         Atkins
Peter Dennis           APEM
Rachael Dils           Environment Agency
John Douglass          Environment Agency
Bob Evans              Anglia Ruskin University
Chris Extence          Environment Agency
Liz Finch              Defra
Kirsten Foot           Environment Agency
Ian Foster             University of Northampton
Sheila Greene          Centre for Ecology and Hydrology
Crispin Hambidge       Environment Agency
Barry Hankin           JBA Consulting
Bob Harris              Defra
Jane James             Heathside Consulting
Penny Johnes           University of Reading
Iwan Jones             Queen Mary, University of London
Dave Kay               University of Aberystwyth
Cedric Laize           Centre for Ecology and Hydrology
Andrew Lovett          University of East Anglia
Dan McGonigle          Defra
Ian Milligan           APEM
Russ Money              Natural England
Pam Naden              Centre for Ecology and Hydrology
Gareth Old             Centre for Ecology and Hydrology
Nick Paling            Westcountry Rivers Trust
Haydn Probert          Wye & Usk Foundation
Sim Reaney             University of Durham
Andrew Richman         Environment Agency
Lindsey Stewart        Natural England
Marianne Stuart        British Geological Survey
Russell Todd           Defra
Helen Wake             Natural England
Michelle Walker         The Rivers Trust
Louise Webb            Environment Agency
Paul Whitehead         University of Oxford
Anthony Williamson     Environment Agency
Susie Willows          Defra
Ting Zhang             University of Lancaster/CEH
Yusheng Zhang          ADAS
Appendix II

Compendium of Methodologies, Tools, GIS layers and Datasets
**ASPIRE (Agricultural Sediment Pressures and Impacts on Riverine Ecology)**

ASPIRE is a prototype national scale (England and Wales) modelling framework coupling agricultural sediment delivery to watercourses (APT model sediment module) and biotic endpoints for macroinvertebrates and fish (salmonids). The prototype tool has been developed as part of Defra project WQ0128: *Extending the evidence base on the ecological impacts of fine sediment and developing a framework for targeting mitigation of agricultural sediment losses*.

**Spatial targeting**
The national scale modelling framework provides a basis for:
- screening waterbodies for selecting those where agriculture is the dominant source of sediment pressure on rivers
- screening individual waterbodies or groups of waterbodies to identify hotspots contributing the most to agricultural sediment pressure
- *spatial targeting*: for any given area (one or more of 3380 amalgamated WFD Cycle 1 waterbodies across England and Wales), mitigation can be implemented in the 1km² grid cells that contribute a fixed percentage of the total catchment agricultural sediment load. This functionality provides a basis for assessing the relative cost-effectiveness of targeted versus blanket application of on-farm mitigation methods.
- *optimisation*: for any given area, a suite of mitigation methods can be selected, and the tool will generate a ‘cost-curve’, showing the most cost-effective order in which to implement those methods. This is achieved by ranking the cost-effectiveness of each of the mitigation methods and selecting the most cost-effective. The remaining methods are then reassessed, taking into account the method that has already been implemented, and the next most cost-effective method is selected. This process is repeated until all methods have been selected, producing a summary cost-curve graph.

**Background**
Agricultural sediment pressure is modelled using a new national scale (England and Wales) daily time step model. This new model is founded on the continued refinement and development of previous Defra-funded inorganic sediment modelling (PSYCHIC, Defra project PE0202), which under Defra project WQ0100NIT, has been superseded by the APT (ADAS Pollutant Transport) framework. The APT sediment module has been designed to be:

- sensitive to appropriate input weather, soils and management practice data
- responsive to simple inputs available from basic farm survey data
- representative of multiple pollutants (sediment, phosphorus, nitrate)
- operational on a daily time step
- scalable to catchment or national level simulations for policy support.

The APT framework operates initially at a field scale, to calculate drainage and pollutant losses, with a separate catchment scale component to determine net delivery between fields and watercourses. For a national scale simulation, statistical data can be used to generate the field scale data needed to run the framework. The pressure modelling represents sediment mobilisation and delivery and, critically, is capable of calculating seasonal loads delivered to river systems for integration with representation of the key life stages of a range of biota.
The baseline sediment pressure results from the APT sediment module are in the absence of mitigation. The potential or expected impacts of a suite of 18 different mitigation methods (Table below) can be assessed for their consequences on sediment and organic carbon (from manures) pressures, and also for their costs of implementation.

Mitigation methods simulated in the ASPIRE framework

<table>
<thead>
<tr>
<th>ID</th>
<th>Method Name</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Establish cover crops in the autumn</td>
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<tr>
<td>2</td>
<td>Cultivate land for crops in spring rather than autumn</td>
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<tr>
<td>3</td>
<td>Manage over-winter tramlines</td>
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<tr>
<td>4</td>
<td>Cultivate compacted tillage soils</td>
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<tr>
<td>5</td>
<td>Loosen compacted soil layers in grassland fields</td>
</tr>
<tr>
<td>6</td>
<td>Cultivate and drill across the slope</td>
</tr>
<tr>
<td>7</td>
<td>Establish in-field grass buffer strips</td>
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<tr>
<td>8</td>
<td>Establish riparian buffer strips</td>
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<tr>
<td>9</td>
<td>Establish new hedges</td>
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<tr>
<td>10</td>
<td>Reduce the length of the grazing day/grazing season</td>
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<tr>
<td>11</td>
<td>Reduce field stocking rates when soils are wet</td>
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<td>12</td>
<td>Move feeders at regular intervals</td>
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<tr>
<td>13</td>
<td>Construct troughs with a firm but permeable base</td>
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<tr>
<td>14</td>
<td>Use slurry injection techniques</td>
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<tr>
<td>15</td>
<td>Incorporate manure into the soil</td>
</tr>
<tr>
<td>16</td>
<td>Do not apply manure to high-risk areas</td>
</tr>
<tr>
<td>17</td>
<td>Do not spread slurry or poultry manure to fields at high-risk times</td>
</tr>
<tr>
<td>18</td>
<td>Do not spread FYM manure to fields at high-risk times</td>
</tr>
</tbody>
</table>

The macroinvertebrate endpoint in ASPIRE is represented by a new sediment sensitivity index; the combined species-level Fine Sediment Index (coFISisp). Coupling modelled agricultural sediment pressure (without and with mitigation methods applied) with coFISisp provides a basis for calculating the change in the Fine Sediment Index scores in conjunction with a range of mitigation strategies. Coupling agricultural sediment pressure and the macroinvertebrate index can be undertaken at national scale. The fish endpoint is represented by the Sediment Intrusion and Dissolved Oxygen (SIDO-UK) model which has been calibrated for a small number of test catchments. This aspect of the integrated modelling framework provides a basis for exploring the potential benefits of spatially targeted/optimised mitigation strategies for the survival of salmonid species.

Scale and data requirements

ASPIRE covers England and Wales although the coupled modelling linking agricultural sediment pressure and the fish endpoint only covers a select number of test catchments. SIDO-UK needs to be calibrated for new test sites to improve the spatial coverage of this component of ASPIRE.

Applicability

National screening; waterbody screening; national coupling of agricultural sediment pressure and the macroinvertebrate endpoint; coupling of agricultural sediment pressure and the fish endpoint for select test catchments only.
Known limitations
ASPIRE is a prototype and much further work is required to continue refining its core components.

Availability
ASPIRE is a prototype tool and is not freely available at this stage. The tool can be run on a bespoke basis and such applications can be discussed with the lead contact. Summary GIS layers can also be provided to support targeting decisions.

Expertise needed
The biotic endpoint for macroinvertebrates needs to be used in conjunction with RICT to assess the potential for closing the gap to good ecological status on the basis of spatially targeted and/or optimised mitigation methods for the agricultural sector.

Example applications
ASPIRE has been used to assess the technically feasible reductions in agricultural sediment pressure associated with individual mitigation methods and combinations thereof, following these changes through to the biotic endpoints.

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References
The Source Apportionment GIS (SAGIS) tool

SAGIS is funded by UKWIR, Environment Agency and SEPA and brings together a wide range of data sources on chemical substances in a GIS. These are used within an upgraded version of SIMCAT to simulate the impact of different sectors, in terms of source apportionment, to river water quality, lake water quality, coastal and estuary waters. Both visualisation tools and the ability to perform “what if” scenarios are provided.

Spatial targeting
- identification of sector contributions to nutrient concentrations in rivers at national, regional and catchment scales
- impact of chemical loads on lake water quality, coastal waters and estuary loads

Background
National datasets currently include: PSYCHIC model outputs for agricultural phosphorus and soil loss, NEAP-N outputs for agricultural nitrate, minewater loads, highway runoff, CSO/storm tank overflows, small wastewater treatment works and septic tanks, atmospheric inputs, effluent quality and river monitoring data. Chemicals of interest are nutrients (P and N), metals (Cu, Zn, Pb, Ca, Ni and Hg), organics (di-ethylhexyl phthalate and PAHs). SIMCAT is the basis for the water quality compliance assessment for chemical concentrations and identification of the main sector responsible for non-compliance.

Applicability
National/regional assessments of river water. Being extended to include source apportionment to lakes and lake water quality.

Known limitations
Plans to link with other models e.g. Farmscoper for agricultural diffuse pollution mitigation. Missing sectors: contaminated land, landfills, urban pollution.

Availability
Launched about a year ago. Trying to promote community use with a user group website and user forum being set up; working on intellectual property issues which restrict access.

Example applications
Currently 18 regional models being used by Environment Agency, SEPA, Water Companies (Welsh Water, Severn Trent, Anglian Water, Southern Water, Thames Water and United Utilities) for national planning assessments i.e. disproportionate cost assessment and chemical risk assessment.

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Enhanced national biogeochemical modelling capability through the EVOOp portal

The National Biogeochemical Modelling Framework, developed under the NERC Environmental Virtual Observatory Pilot (EVOOp) programme and supported by cloud computing infrastructure, provides an opportunity to address spatial targeting of waterbodies in the UK where diffuse water pollution from agriculture is dominant.

Spatial targeting
- provides diffuse source contributions of nutrient loads (land use type, livestock type or humans through a range of wastewater treatment typologies) in rivers and concentrations of TN and TP.
- upscaling of nutrient estimates from gridded plots to a range of regional and national water quality management units (river catchment, WFD RBDs, CDUs, OSPAR Zones, country).
- manipulation of current conditions by scenario testing to explore the impact of potential mitigation measures across the range of spatial scales from catchments to national
- facilitates knowledge transfer from data-rich to data-poor environments which are either located downstream from existing monitoring infrastructure, or are in ungauged or unmonitored catchments in remote locations.

Background
The approach adopted has been to develop national biogeochemical modelling capability through the refinement and extension of the geoclimatic region framework for total nitrogen (TN) and total phosphorus (TP) flux modelling (Johnes et al., 2007; Johnes and Butterfield, 2002). Under the EVOOp programme this original framework was refined using the most up-to-date, high-resolution datasets available from national centres and surveys, resulting in a modelling framework that operates at a spatial resolution of 50m across the whole of the UK. Within the EVOOp, the advantages of the National Biogeochemical Modelling Framework were demonstrated using a cloud-computing enabled Export Coefficient Model (ECM) at a spatial resolution of 4km², however data at 1km² is also a possibility.

The geoclimatic region framework comprises a series of nine regional submodels within a national modelling structure (see figure below), and provides separate groups of export coefficients for each geoclimatic region type. These geoclimatic regions represent areas with broadly similar climate, geology, soil types, topography and natural vegetation cover which have, therefore, similar ranges of nutrient export potential (and nutrient retention capacity) as a function of flow volume, timing and routing from land to stream.

Scale and data requirements
An online, cloud-based service is currently available for data describing conditions in 2000. For application of the ECM for years other than 2000, agricultural census data (1km², 4km², 10km²) on land use and livestock, human population, wastewater treatment types, TN deposition and TP in precipitation are needed. Import and export coefficients for the ECM are available in excel format. Calibration of parameters suitable for other models against observed nutrient flux data may be required.

Applicability
Across UK, from 50m to a range of regional and national water quality management units (river catchment, WFD RBDs, CDUs, OSPAR Zones, country).
Known limitations
Seasonal estimates not provided by the export coefficient model. Other sub-annual models which would address this are yet to be brought within the framework.

Availability
Immediate use: no data requirements – an online, cloud-based service is currently available for data describing the year 2000. Immediately available on any PC with internet facilities. For application of the National Biogeochemical Modelling Framework for other macronutrient models the 50m resolution vector GIS layer, in shapefile format and suitable for ESRI GIS systems, is available. Each map unit (polygon) is described by a field id detailing its geoclimatic region, area and boundary.

Expertise needed
Web-based version has a user-friendly interface, with tips to guide and inform users which is aimed at a non-expert intelligent user. No expertise in data handling or modelling required for web-based version.

Example applications
Outputs have demonstrated the dominance of diffuse sources in the TN flux signal nationally. This contrasts with the signal for TP which is more evenly split between diffuse and point sources nationally, but shows significant hotspots associated with urban centres when viewed on a 4km² grid scale with point sources clearly dominating the downstream TP signal. Upstream of major urban centres, diffuse TP sources dominate the loading. Scenarios tested represent conditions appropriate under (1) Good Agricultural Practice policy guidance, (2) additional mitigation measures appropriate to the delivery of reduced diffuse P fluxes to support WFD compliance, and (3) addition of measures to ensure compliance with the standards required under the EU Urban Wastewaters Treatment Directive (UWwTD) to all sewage sources in the UK. At present UWwTD compliance is only required for larger wastewater treatment works (WwTW) serving a population equivalent to greater than or equal to 10,000 persons. The scenario testing suggests that even with all measures in place, a maximum of 58% reduction in P export and 30% reduction in N export would be possible, with the greatest rates of reduction in P export occurring in major urban centres, while the greatest rates of N export reduction occur in rural areas.

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References
The National Biogeochemical Modelling Framework, revised and extended to include Scotland and Northern Ireland, comprises the first standardised biogeochemical modelling framework for the UK (Greene, S., Johnes, P.J., Bloomfield, J., Reaney, S., Freer, J., MacLeod, K., Odoni, N., Lawley, R. (in preparation) Enhanced nutrient flux predictive capabilities using a national modelling framework).
SCIMAP

SCIMAP is a risk-mapping framework designed to identify where in the landscape diffuse pollution is most likely to be originating. SCIMAP does not try to make quantitative predictions in real world units (e.g. mg l\(^{-1}\)) but rather works in relative terms across the landscape and identifies the most probable sources of the observed problem. SCIMAP considers the spatial pattern of source risks and connectivity to create risk maps of the diffuse pollution risk concentration within river channels. These maps can be used to spatially target mitigation measures. It is important to consider SCIMAP as an approach, a risk mapping framework, rather than complete solution. Standard SCIMAP provides a method and tool set which can then be tailored to the application required. It has been tested against ecological and water quality datasets (N and P) for a range of UK catchments. The ‘fitted’ version of the approach enables SCIMAP to be applied to a wider range of pollutants provided they are consistent with the underlying assumptions of the approach. There is a video on the website which introduces SCIMAP: http://wp.me/p2nG4Y-7k

Spatial targeting
SCIMAP aids spatial targeting by identifying the locations in the landscape that are most likely to be contributing to an observed diffuse pollution issue. SCIMAP should be used as part of a toolkit. Given that a suitable large-scale catchment (e.g. 2000 km\(^2\)) has been identified as having water quality issues thought to be related to diffuse pollution, SCIMAP can then identify the key locations within this landscape where the combination of source risks and connectivity lead to their probable source. These locations can then be investigated in more detail on the ground, in case of features not represented in the input data/model. At the end of this process, SCIMAP can identify the sub-catchments, fields, and flow paths within the fields, at the scale of five metres or less, that are of high risk of exporting diffuse pollution.

Background
SCIMAP is based on the identification of locations of critical source areas (Heathwaite et al., 2005) within the landscape. These locations are based on the areas that are most likely to have a source of the pollutant of interest and have an active connection with a water course. Within the SCIMAP approach, the most appropriate information on the sources and connections needs to be selected by the user. In the standard version of SCIMAP, the sources are related to land cover as a proxy for land use and management, on a similar basis to Export Coefficient models such as Johnes (1996). The connectivity predictions are based on the Network Index (Lane et al., 2004) which traces each individual flow path across the landscape to determine how wet the landscape must be to both generate runoff and connect to the river channel. The standard approach utilises the topographic wetness index (Beven and Kirkby, 1979) to make spatial predictions of soil moisture but these maps can be based on observations or physically-based hydrological model simulations (Lane et al., 2009). It is important to ensure that the assumptions embedded within the predictions of patterns of soil moisture, connectivity and source risks match with the environment under study.

Scale and data requirements
SCIMAP can be run across large catchment (≥ 2000 km\(^2\)) as well as for targeted sub-catchments (e.g. < 1km\(^2\)). The normal grid resolution is 5 m based on the NextMap DEM product therefore giving large coverage whilst maintaining fine spatial detail at the sub-field scale.
Key data requirements for standard SCIMAP are:

- DEM – NextMap 5 m is the standard data source; the approach can be run with finer topographic information, such as LIDAR. The OS 10 m Profile DEM can also be used but is not preferred and care must be taken to check the results.
- Land Cover information – the standard is the CEH Land Cover Map 2007 coupled with a default set of risk weightings. The risk weighting can be updated based on local knowledge. Other land cover information can be used. It is possible to generate land cover / land use change maps outside of SCIMAP and import these to consider how these change the spatial pattern of risk.
- Rainfall patterns – this is normally based on the Met Office 5 km long-term average data grid for the UK. If more up to date or detailed information is available, then this can be used.

SCIMAP Fitted also requires a spatial dataset of the pollutant, chemical or species of interest. The pollutant or chemical information can be based on the EA GQA dataset and the species information could be based on spatial electro-fishing datasets.

**Applicability**

The standard implementation of the SCIMAP framework is applicable where topographic controls dominate the movement of water and pollutants through the landscape. Thus, SCIMAP is widely applicable in many parts of the UK. However, SCIMAP is not applicable in areas of pumped hydrology with ditches, areas with minimal topographic relief or groundwater-dominated areas.

**Known limitations**

The key limitation with an application of SCIMAP is the quality of the input data (garbage in, garbage out), therefore, care must be taken to use datasets with the required level of spatial information. Many small-scale management features are not represented in commonly-used spatial datasets. Identified sites from SCIMAP should be followed up with a ground visit.

**Availability**

SCIMAP is available under a Creative Commons non-commercial licence meaning that it is free for non-commercial use. SCIMAP Standard is currently implemented within SAGA GIS (available at [www.scimap.org.uk](http://www.scimap.org.uk)). A web-based version of SCIMAP is currently under development (target launch date is for autumn 2013) which will allow for simpler access to both the standard and fitted versions of SCIMAP. SCIMAP is not currently directly supported by Durham University.

**Expertise needed**

Users need to understand the key hydrological processes within their area of interest and have basic GIS skills. The web-based version of the tool will be simpler to use and will be supported by a set of training resources. The user needs to understand what the results mean and to ensure that the assumptions fit their area of interest. This level of critical analysis of the output is required for any model prediction but needs to be stressed.

**Example applications**

SCIMAP has been applied to the identification of pressures on salmon and trout in the River Eden catchment (Reaney et al., 2011), to the identification of source areas for N and P in CSF catchments in England (Millegde et al., 2012) and to support the Nitrates Directive in Ireland (Wall et al., 2011).
There are also videos of how the West Country Rivers Trust (http://wp.me/p2nG4Y-6K) and the Yorkshire Dales Rivers Trust (http://wp.me/p2nG4Y-6H) have used SCIMAP.

Example application of SCIMAP to the Morland Beck catchment, Cumbria

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References
Using Scimap to target in-field measures

SCIMAP is a particularly powerful tool combining land use risk, slope and rainfall data to produce a map showing areas of the catchment which generate diffuse pollution and which are hydrologically connected to a watercourse and thus present a high risk of diffuse pollution to water. This entry represents the experience of the Wye and Usk Foundation in using SCIMAP for a targeted campaign on risky management practices within the Wye Herefordshire Improvement Project 2 (WHIP2).

Spatial targeting
SCIMAP provides accurate graphics in relation to both farm scale and catchment scale land management; it identifies and assists with targeting across broad spatial scales. This is reached by assigning a risk probability framework to a landscape and can be powerful tool in directing mitigation measures most effectively.

Background
The morphology, topography and geology of the Herefordshire Wye make it highly susceptible to sediment loss and diffuse pollution. Coupled with that and the fact that this area is put under very high pressure from farming, there is an increase in sediment loss of 10-20 times that of the national average.

Scale and data requirements
The Wye and Usk Foundation currently only has three sets of data which have been incorporated into the SCIMAP software to produce erosion risk maps. These are:
- height data (DEM) with 5 m resolution to aid more accurate outputs
- land cover data from 2007 which holds information about specific land use; this layer is constructed from individual parcels of land with relevant data attributed to them; can be updated by farm advisors to known current land use
- rainfall in a GIS layer derived from UK Met. Office data which shows the average rainfall for the specific area.

Applicability
The SCIMAP erosion risk maps produced from the three data sets are applied directly to individual farms that pose the greatest threat of current and future risk of surface runoff and erosion. The erosion maps that are created highlight the areas within the catchment that are more vulnerable to erosion. From this, farm-specific maps are produced to show farm advisors the key areas to focus on and subsequently develop implementation strategies to overcome the particular issue.

Known limitations
SCIMAP results will only be as accurate as the data incorporated into the model. Known limitations for farm-specific management include:
- no micro features such as gateways, farm tracks and drains as standard; these can be manually programmed into the data and current application includes all known drainage routes (i.e. includes ditches and drains) thus providing more accurate output.
- soil structure is not taken into account; this can be modified in the input data but is costly and time consuming.
- subsurface flow is not included, which indicates SCIMAP is more appropriate for surface-water dominated catchments.
- roadways are not included which will potentially have an impact on flow routing and connectivity of surface flow.

**Availability**
- limited access of up-to-date land classification limits the accuracy of the SCIMAP model outputs.
- the process of producing these erosion maps does not take a great deal of time and known discrepancies within the data sets can always be edited if needed. However, with limited funding it is not easy to access up-to-date data within project timescales.

**Expertise needed**
- trained personnel with good knowledge of using both GIS tools to pre-process data sets, and use of the SCIMAP modelling tool.
- adequate training is essential in understanding how to handle the data and use the software correctly.

**Example application**
Below is an example of how The Wye and Usk Foundation use SCIMAP to produce farm specific erosion maps and how it is applied in a farm advisory service. The map highlights areas within the farm that are at high risk from erosion during surface flow events.

Farm advisors use maps such as the one above to highlight to the farmer the areas at risk and apply their knowledge to advise on the implementation of measures to combat possible effects. This method is applied to the whole area within the catchment restoration funded project and will later be rolled out in other areas of the catchment.

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**PEDAL tool**

The Defra-funded PEDAL2 project has developed a tool to look at the effect on phosphorus loss of placing agricultural diffuse mitigation measures (buffer strips and wetlands) within a catchment.

**Spatial targeting**
- placement of mitigation measures (buffer strips and wetlands) for diffuse agricultural phosphorus pollution
- assessment of effects on phosphorus loss at local and catchment scale

**Background**
The PEDAL tool brings together datasets and expertise to model the source, mobilisation and delivery of phosphorus to rivers. A delivery coefficient is defined as the ratio of delivered P to mobilised P. Mobilised P, represented by the DESPRAL value, is derived from soil information (soil texture and Olsen P). The delivery coefficient is a function of rainfall, baseflow index and drainage density. Application of the delivery coefficient to the DESPRAL value gives P loss.

**Scale**
Catchment scale.

**Applicability**
Model looks at buffer strips and wetlands – rules have been developed for both local effects and catchment-wide impact.

**Known limitations**
Currently developed for phosphorus; information for FIOs but less confidence so not included.

**Expertise needed**
GUI interface for scenario testing.

**Example applications**
Ribble catchment

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ECM+

The ECM+ model has been developed to facilitate participatory catchment planning and target catchment management measures.

Spatial targeting
- sub-catchment by sub-catchment source apportionment
- scenarios for uptake and targeting of mitigation measures

Background
The model is essentially an export coefficient model for phosphorus (SRP), nitrogen (DIN), sediment and FIOs which has been extended to incorporate roads/tracks and linked to the SPARROW model (Smith et al., 1997) for in-channel and in-lake processes. Export coefficients are derived from the literature for each source (agricultural crop types and animals, domestic septic tank systems, STWs and roads/tracks). The export coefficients are optimised against measured concentrations using Monte Carlo simulation for each sub-catchment. This provides an uncertainty range on both export coefficients and load apportionment. Current uptake of mitigation measures, as advised by farmers, is included along with the associated reduction in export according to scientific opinion.

Scale and data requirements
Catchment or sub-catchment scale.
Date required:
- Environment Agency water quality monitoring data, 2007-2012, for all monitoring stations within the study catchment. Parameters required include phosphorus, orthophosphate, oxidised nitrogen, ammonium, nitrate, nitrite, inorganic nitrogen and suspended solids.
- Environment Agency precipitation data, 2007-2012, for all monitoring stations within the study catchment.
- A good quality digital terrain map at 5 m resolution:
  - from which water bodies, roads/tracks and buildings can be extracted
  - and for stream network delineation.
- Landcover Map 2007 at 25 m resolution to calculate agricultural, woodland, urban and ‘other’ areas per sub-catchment.
- Agricultural Census 2010 to calculate agricultural land use areas (including cereals, oilseed crops, peas/beans, potatoes/sugar beet, horticulture, maize, fodder crops, temporary grassland, permanent grassland, rough grazing and bare fallow) and livestock numbers (including sheep, poultry, cattle and pigs) per sub-catchment.
- Sewage Treatment Works data including location, population equivalent served, treatment type and information on nutrient removal.
- Percentage uptake of farming Best Management Practices per sub-catchment.

Applicability
Phosphorus (SRP), nitrogen (DIN), sediment and FIO concentrations and loads with uncertainty; cross-sector source apportionment (agriculture, roads/tracks, septic systems and STWs) with uncertainty. Ability to run “good farm/bad farm” scenarios and the effect of uptake of measures.
Known limitations
Source apportionment different to SAGIS model and this is the focus of a current collaboration between West Country Rivers Trust and South West Water.

Expertise needed
- Experienced personnel with good knowledge of using GIS tools to pre-process datasets.
- Experienced personnel with a thorough understanding of the ECM+ to facilitate participatory workshops with stakeholders.
- Very specific expertise is needed in calibrating the model.

Example applications
Tamar catchment: Focus on Caudworthy Water sub-catchment with mitigation measures implemented using capital grants under CSF, infrastructure funding by Westcountry Rivers Trust and on-farm investment by South West Water being coupled with detailed monitoring by DTC programme. ECM+ has been used extensively to characterise the load, concentration and source apportionment of nutrients, sediment and FIOs in the Tamar Catchment at the whole- and sub-catchment scale.
South Hams: Participatory workshops with stakeholders to carry out nutrient budgeting for the transitional and coastal waterbodies surrounding the South Hams coast.

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References
Faecal Indicator Organisms: a screening tool and spatial targeting of BMPs

There is a problem of bacterial pollution of bathing and shellfish waters, essentially from human sewage, combined sewer overflows, urban diffuse sources and livestock farming. The evidence base for Faecal Indicator Organisms (FIO) export coefficients and effectiveness of best management practices (BMPs) is increasing but is still sparse compared to nutrients.

Spatial targeting
- export coefficient model for screening; can also be used as a management tool for looking at deviations from measurements to define hotspots
- evidence for effectiveness of BMPs: on-farm storage without replacement is effective in attenuating FIOs (118 days for fresh faeces, 8 days FYM and 69 days slurry); stock exclusion from streams can significantly reduce FIO high-flow flux (e.g. Brighouse Bay 60% all streams fenced on both sides and gave 50-80% reduction); small farm ponds only provide small reduction and often leak so not effective; constructed wetlands work extremely well but have huge land-take.

Background
The acquisition of basic data on FIOs is difficult as 97% load occurs in storm flows (i.e. <10% time). There are now 300 subcatchments in the database with land use mapping. Using these data, a screening tool has been developed using regression analysis to provide export coefficients for different land uses. However, these are national averages so should only be used for screening purposes, not as a predictive tool. The effects of best management practices are generally based on expert opinion but there is now a growing literature (although not much data from the UK) providing evidence.

Scale and data requirements
Application is at the small catchment scale 2-100 km². To acquire the field data and design appropriate experiments, capturing events is key and manual sampling is essential for high quality data.

Example applications
Brighouse Bay, Pwllpeiran Wetlands, Scottish Ponds Project, Coastal schemes

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References


Catchment-scale characterisation using Fieldmouse

Fieldmouse simulates the transport of pollution at the field scale via the physical landscape to understand the impacts on local watercourses, and enables the assessment of measures to improve farm management practices. Fieldmouse is funded through the Catchment Sensitive Farming (CSF) project; it is designed to address weaknesses in the evaluation of CSF but is a flexible tool and may be able to provide a generic source to receptor routing method.

Spatial Targeting
- identifies holdings (or other sources of pollutant) that contribute most to river loading
- allows for identification of holdings that will best respond to intervention measures, allowing users to locate target holdings or to optimise packages of measures.

Background
In the application of CSF, good spatial targeting is vital. Traditionally, work has been focussed on passive targeting (catchment characterisation etc). Previous attempts at explicit targeting have lacked detail in the pathway section of the source-pathway-receptor model (Williamson et al. 2011). Fieldmouse was designed to fill this gap in the CSF targeting work. This fits with current EA thinking that science effort should be put into understanding and enhancing effectiveness of measures (personal communication Baxter 2013).

There is currently no generic method of source to receptor transfer; this limits the ability of landscape models to be used to target effort on the ground. Many landscape export models either lack field to river transport or implement a simple method, thus an important element of the system is marginalised (Anthony et al., 1996; Davison et al., 2008). Fieldmouse was designed from the beginning to be flexible and open to incorporation with other modelling systems.

The novel element of Fieldmouse is in the use of the Soil and Water Assessment Tool (SWAT) model to generate a look up table of physically-based decay parameters based on slope, land use and soil type (Gassman et al., 2007). The use of the lookup table allows for the model to be based on physical understanding of catchment processes, but retain the benefits of conceptual simplicity and computational efficiency. Gassman et al. (2007) demonstrate several successful implementations of the SWAT approach.

Fieldmouse has two transport mechanisms: overland flow and throughflow. The split is determined based on the Continuous Estimation of River Flows (CERF) long-term average quick flow and slow flow outputs (Griffiths et al. 2008). Several studies, including Heathwaite and Dils (2000), have quantified differing delivery rates of nutrients via overland flow and throughflow.

The conceptual simplicity and visual outputs of Fieldmouse give the model the ability to be used in a participatory modelling environment. The benefits of participatory modelling in terms of improved model acceptance by stakeholders and policy makers have been outlined several times (Prell et al., 2007; Kruger et al., 2012).

Scale and data requirements
- Tested on catchments up to 450 km²; there is no practical reason why larger catchments would cause problems.
- Requires ArcGIS 9.3 or greater with the spatial analyst extension.
- Data requirements: DTM (ideally 10m or finer), DRN (or another river network with connectivity defined), source of diffuse load, point source loads and flows, CERF, catchment boundary, water quality monitoring data for calibration, river flow monitoring data for calibration.
Applicability
Not yet fully tested but, like similar models, may have difficulties in catchments with significant groundwater/surfacewater interactions. The representation of hydrology may need to be improved before Fieldmouse is useful in catchments with low drainage density.

Known limitations
High level of spatial detail has been at the expense of temporal and process detail (especially in the river module). A separate INCA-based spreadsheet model has been produced to counter these limitations, but transfer between the two is difficult (it is likely the spreadsheet model will not be as freely available as Fieldmouse).

Availability
Will be free for non-commercial use; a fee will be payable for commercial use
Or
Fieldmouse will be released under an ‘open’ licence. Licensees will be free to use, copy or adapt as they wish.

Expertise needed
Basic ArcGIS skills

Example applications
River Wyre and River Nadder

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References
Empirical nutrient load apportionment modelling

This load apportionment model is based on the timing of pollutant inputs and differentiates between constant sources and rainfall-related sources. It uses the observed relationship between nutrient concentration and river flow at a site.

Spatial targeting
- rapid assessment to differentiate sites dominated by constant or rainfall-related loads
- prediction of effects of STW improvements on overall nutrient concentrations

Background
The model is based on the premise that constant inputs will show dilution as river flow increases, while rainfall-related inputs will increase with increasing flow. Constant inputs include sewage treatment works, industrial inputs and septic tank misconnections. Rainfall-related inputs include diffuse pollution (agriculture, septic tank soakaways, road runoff, combined sewer overflows) and within-channel mobilisation.

Scale and data requirements
Catchment scale; requires continuous flow data and sampled nutrient concentrations (minimum of one year of weekly data or 3-5 years of monthly data). The spatial resolution is determined by the availability of these data. The model produces source apportionment for the entire catchment upstream of the chemistry monitoring point.

Applicability
Any site with appropriate data; simple and rapid technique based entirely on the relationship between nutrient concentration and river flow. Daily time step ensures that seasonality is taken into account.

Known limitations
Not effective if within-channel nutrient dynamics are high as this can lead to substantial underestimation of the point source contribution. New developments of the model (Jarvie et al., 2012) can deal with this for large rivers in the US with infrequent sewage inputs. Only differentiates between constant and rainfall-related inputs but even this will point to different mitigation requirements which can be assessed further.

Expertise needed
MS Excel-based spreadsheet tool so no specialist expertise required

Example applications
Large rivers in eastern England, Frome, Thames basin, East Anglia, Ireland, Leicestershire.

Example below shows River Cole at Lynt Bridge. Although total phosphorus load is greater from diffuse sources, the majority of the time during summer months is dominated by point source contributions. This means that in order to reduce the risk of algal blooms, constant sources i.e. STW inputs, need to be targeted.
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References
National layers being developed within WQ0223

At the national scale, Defra-funded project WQ0223 Developing a field tool kit for ecological targeting of agricultural diffuse pollution mitigation measures will help to identify WFD catchments and lakes where mitigation of diffuse agricultural pollution is likely to improve the ecological status. It will provide GIS layers at WFD water body level, using the WFD Cycle 2 boundaries, for

- nutrient and sediment concentrations for ecological windows for inputs from cross-sector sources (diffuse agriculture, river channel banks, urban, industry, highway, septic tanks, intermittent discharges, small and main sewage treatment works)
- time scale and magnitude of nitrate legacy from groundwater
- identification of lakes likely to benefit from reduced phosphorus from agricultural sources, as distinct from those where other sources of P, such as bottom sediments, are important and require other types of management intervention
- collated information for identifying where the ecology is likely to be constrained by hydromorphological influences (physical modification to river channels, lack of connectivity and poor quality of riparian zones, and reduced flow)
- estimated reduction in agricultural pollutants due to mitigation as predicted by FARMSCOPER runs under a range of scenarios (COGAP, Farm Assurance, ELS, ETIP, GHG AP, CSF, Greening of Pillar 1, candidate ‘basic’ measures for article 11.3, low cost methods, all of these, present regulation with 50% and 100% compliance, present regulation with 100% compliance plus ‘basic’ measures).

Spatial targeting

- prioritising areas where mitigation measures are likely to produce results in improved ecological status i.e. areas where diffuse agricultural water pollution is the dominant influence on water quality, the gap has potential to be closed by available measures and other factors such as legacy issues or hydromorphology will not compromise results
- providing explanation for those cases where mitigation measures have been implemented but there is no/little observed improvement in ecological status

Availability

This is a three-year Defra-funded project (2012-2015) and the GIS layers developed will be provided to Defra and will be available for use by WFD co-deliverers. Many of the GIS layers will be delivered by early 2014; the work on lakes occurs later in the project.

Other work in the project is designed to enhance the evidence base relating to ecological sensitivity in relation to multiple stressors and ecological recovery and to provide a field tool kit to guide practical application. It is anticipated that the field tool kit will link directly into the national-scale layers.

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Use of freshwater ecological data and metrics in spatial targeting

Biological Quality Elements are the end points for the Water Framework Directive and data are collected on both a routine and project-specific basis. Ecology is sensitive to a range of stressors and a number of diagnostic indices have been developed to determine these. Focus is on the use of biological data to identify stressors and enable identification of appropriate measures to reduce them.

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Spatial targeting
Biota can be useful in identifying stressors and hence appropriate mitigation measures; can be linked to models/tools (e.g. ASPIRE – see above)

Known limitations
Ecology responds to multiple stressors

Availability
Widely used by Agencies and generally available e.g. RICT tool for invertebrate indices
http://www.sepa.org.uk/science_and_research/what_we_do/monitoring_and_reporting/ecology/ric.aspx

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Remote sensing tools

The Environment Agency Geomatics Unit has been developing an integrated toolbox approach to remote sensing for catchment management services using a variety of remote sensing instruments, including LIDAR and CASI. These provide many different services from one survey flight. The survey flight is generally the most expensive element of remote sensing so, the more genuinely useful products that can be extracted from the data, the more cost effective the survey flight becomes. From one single survey flight we are able to determine: probable overland flow routes, bare soil extent and location, farm scale tools for evidence-based stakeholder engagement, evidence about agricultural management practices, field boundary mapping, riparian vegetation cover and shade.

Spatial targeting
It provides robust evidence at catchment and farm scales for targeting costly farm walkovers; it may also provide products for use in other models.

Background
Uses standard image processing/GIS techniques in software packages (e.g. ERDAS/ArcGIS)

Scale and data requirements
LIDAR, CASI, Worldview-2 satellite data. Spatial resolution: 0.5 m to 2 m.

Applicability
All catchments: pastoral and arable, upland and lowland.

Known limitations
Initial survey cost (although much of this can be mitigated by making use of Archived LIDAR data), expertise and software requirements (most of the products can be generated using industry standard GIS software packages and training can be provided to enable users to get the most out of the data sets). Surface products so flow paths do not include drains; instant in time.

Availability
LIDAR archive is already extensive and covers approximately 75 percent of England and Wales (less so in Scotland). Either CASI or satellite data would need to be captured for the optical elements.

Expertise needed
GIS and remote sensing, as well as knowledge of farm management practices.

Example applications
Overland flow modelling; defining topographically robust watersheds; bare soil mapping; riparian vegetation cover and shading; evidence of channel realignment; crop management mapping; field boundary mapping; digital surface models; digital terrain models; shaded relief maps; surface object models; slope maps; aspect maps; contour maps; 3D visualisations

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3D visualisation tools

Conversion of spatial data in a GIS into different forms of 3D landscape visualisation, including still images, interactive models and content in virtual globes (e.g. Google Earth).

Spatial targeting
Demonstrates how a landscape may change in an intuitive (and possibly interactive) manner which facilitates engagement and discussion with stakeholders.

Scale and data requirements
Needs the underlying spatially referenced data. Can be applied at a range of scales.

Known limitations
Preparation time, especially if high levels of detail are needed.

Availability
Tools exist now.

Expertise needed
Background in GIS or CAD. Some of the software tools have a steep learning curve.

Example applications

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References
Ground Surveys to inform Agri-environment Measures for Mitigating Diffuse Water Pollution

Ground surveys and working with the farmer to develop farm plans are critical to the delivery of benefit from agri-environment measures. Specialist walkover surveys are used within failing WFD waterbodies to identify locations of diffuse pollution and to assess their contribution. These data provide the basis for engagement with the local community and individual farmers to develop farm plans for mitigating pollution. This is coupled with ongoing ecological monitoring.

Spatial targeting
Ground survey methods used to
- identify priority sources of diffuse pollution
- verify their contribution to the problem
- work with farmers to develop farm plans for implementing mitigation measures

Scale and data collected
At subcatchment scale, entire river bank is walked in order to identify locations (hot spots) of diffuse pollution (arable, livestock, roads/tracks, domestic etc); all hotspots are visited when rain is forecast to capture data as each source starts to flow in order to verify contribution and cause (e.g. total nitrogen associated with poor practice such as inappropriate slurry spreading).

Application of data to mitigation
The data are used to produce a Catchment Information Pack for everyone in the catchment to get them involved; a workshop is held for the local people; farm visits are made and, in collaboration with the farmer, farm plans are developed to mitigate the diffuse pollution.

Example applications
Nearly 40,000 km river bank have been walked in work commissioned by the Environment Agency and monitoring undertaken at over 30,000 sites. Nearly 2000 were bad enough to change the WFD classification. From this developed specialist surveys to help improve failing water bodies e.g. Yorkshire Best Practice Project.

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Farm-scale targeting to combat soil erosion by water

As the result of field walkovers, a dataset has been compiled comprising estimates of erosion made in 1700 farmers’ fields 1982-1986. Air photos have been interpreted and field visits made in 17 localities with about 700 km² surveyed each year.

Spatial targeting
The data show that particular soil landscapes are more or less vulnerable to erosion, so erosion is more extensive in some landscapes than others. Some soils (silty and sandy) are more vulnerable than others as are some landforms (slopes below convexities, minor dry valley floors or depressions) and where a wide range of crops is grown (sandy soils) erosion will be more extensive.

Scale and data collected
Farm scale: field mapping is based on 1:10,000 air photos; base maps OS 1:25,000.

Known limitations
Might not have located every rilled field on transects but probably missed very few. Did not estimate sheet/wash erosion – see Evans (2006).

Availability
Dataset is available for 16 localities in England and one in Wales in an Excel spreadsheet.

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References