Section A The fields in this section are mandatory.		
Institution: Durham University		
Unit of Assessment: 14 Geography and Environmental Studies		
Title of case study: Evidence-based catchment management with SCIMAP		
Period when the underpinning research was undertaken: Between 2004 and 2017		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Dr Sim Reaney	Assistant Professor of Physical Geography	February 2005 to present
Professor Stuart Lane	Professor of Physical Geography	June 2004 to January 2011
Dr David Milledge	Postdoctoral Research Associate	September 2008 to June 2018
Period when the claimed impact occurred: Between January 2014 and July 2020		
Is this case study continued from a case study submitted in 2014? Y		
Section B		
1. Summary of the impact		

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Durham University research on how diffuse pollution is connected across river catchments has been used by a wide range of regulatory bodies, NGOs, and user groups in England, Wales, and overseas to improve catchment management. The research developed a model called SCIMAP which is now employed regularly to identify 'hotspots' that can supply pollutants, such as nitrate or fine sediment, into the river system; this knowledge is then used to support management and remediation decisions. Users of SCIMAP include the Environment Agency, which offers the model as part of its central modelling platform; all of the 46 Rivers Trusts that bring together stakeholders in every major catchment in England and Wales; partners in the Catchment-Based Approach (CaBA) that provides a framework for modelling and managing all 100+ catchments in England and eastern Wales under the Water Framework Directive; and a diverse group of NGOs and companies with an interest in assessing and managing diffuse pollution.

2. Underpinning research

A new approach to modelling catchment processes based on the analysis of water flow pathways was developed at Durham University in a 2005-2009 NERC knowledge exchange grant to Durham and Lancaster Universities, led by PI Professor Stuart Lane (Durham), and with co-funding from Defra, the Environment Agency, and the Eden Rivers Trust. Subsequent development of the approach by Durham has involved the active participation of regulatory agencies and other stakeholders in the customisation and application of models within a number of projects from 2008 to present, funded by the Environment Agency, the Ribble Rivers Trust, the EU, and other sources.

The NERC knowledge exchange grant developed a software package called SCIMAP, which is short for Sensitive Catchment Integrated Modelling And Prediction. The approach utilises digital elevation models, land cover maps, hydrological theory, and GIS analysis to map the relative risk of generating a 'problem' (e.g., rapid runoff, fine sediment, nutrients, or coarse sediment) at each cell within a raster-based representation of a landscape, and the likelihood of that 'problem' connecting to a particular river or lake. These 'problems' are then routed along their individual flow paths into and along the stream network, taking into account disconnections and dilution effects, to predict which parts of the network are most at risk. This is scientifically novel in three ways:

- It treats both source risk levels and rapid-flow connectivity as spatially variable over short distances (down to as little as 0.4m), whereas most previous work operated at resolutions of order 1km and either ignored connectivity or treated it in a very simplified way;
- It aims to identify critical source locations of pollution, rather than precisely predicting a particular water quality parameter at a vulnerable downstream location; and
- It can predict the effects of interventions at key source areas or transmission points.

SCIMAP is distinct from other ways of modelling connectivity and pollution by emphasising relative risk, based on sources and network structure, rather than absolute measures of pollutant concentration. This makes the software computationally efficient and maximises its flexibility, so that the outputs can be combined with many other catchment-scale data sets. The re-conceptualisation of the problem (reference **R1**) draws strongly on a sophisticated minimum-information requirement framework for describing hydrological connectivity (**R2**). The approach allows identification of key transmission routes or pollutant source areas, and enables spatial targeting of mitigation actions in the landscape to derive maximum benefit from limited funds. The approach is also not limited to a single pollutant type, and SCIMAP-based tools have been developed and used to track coarse sediment (**R3**), fine sediment (**R4**), nutrients and elements of in-stream ecology (**R2**, **R5**), and microbial pollution (**R6**).

A second major innovation in the research is the close involvement of stakeholders during all stages of the model development and application process. Stakeholders were initially involved in determining questions and specifying outputs in SCIMAP, but subsequently also suggested and evaluated alternative action plans. In the EU-funded Adaptive Land Use for Flood Alleviation project (PI Lane, then Reaney), the project team worked closely with the Eden Rivers Trust to reduce flood risk with minimal impact on agricultural productivity, thus obtaining acceptance by farmers. This engagement formed the pathway to much of the impact described below.

3. References to the research

Note: <u>underline</u> indicates Durham employee during the research and/or at time of publication. Citation data are from Google Scholar, updated 1 September 2020.

R1: <u>Lane</u>, S.N., Brookes, C.J., Heathwaite, A.L., and <u>Reaney</u>, S.M. (2006) Surveillant science: challenges for the management of rural environments emerging from the new generation diffuse pollution models. *Journal of Agricultural Economics* 57, 239-257, doi:10.1111/j.1477-9552.2006.00050.x *(73 citations)*

R2: <u>Lane</u>, S.N., <u>Reaney</u>, S.M., and Heathwaite, A.L. (2009) Representation of landscape hydrological connectivity using a topographically driven surface flow index. *Water Resources Research* 45, W08423, doi:10.1029/2008WR007336. *(Returned to REF2014; 150 citations)*

R3: <u>Lane</u>, S.N., <u>Reid</u>, S.C., <u>Tayefi</u>, V., <u>Yu</u>, D., and <u>Hardy</u>, R.J. (2008) Reconceptualising coarse sediment delivery problems in rivers as catchment-scale and diffuse. *Geomorphology* 98, 227-249, doi:10.1016/j.geomorph.2006.12.028. *(Returned to RAE2008; 66 citations)*

R4: Perks, M.T., <u>Warburton</u>, J., <u>Bracken</u>, L.J., <u>Reaney</u>, S.M., Emery, S.B., and Hirst, S. (2017) Use of spatially distributed time-integrated sediment sampling networks and distributed fine sediment modelling to inform catchment management. *Journal of Environmental Management* 202, 469-478, doi:10.1016/j.jenvman.2017.01.045. *(13 citations)*

R5: <u>Reaney</u>, S.M., <u>Lane</u>, S.N., Heathwaite, A.L., and Dugdale, L.J. (2011) Risk-based modelling of diffuse land use impacts from rural landscapes upon salmonid fry abundance. *Ecological Modelling* 222, 1016-1029, doi:10.1016/j.ecolmodel.2010.08.022. *(Returned to REF2014; 63 citations)*

R6: Porter, K.D.H., <u>Reaney</u>, S.M., Quilliam, R.S., Burgess, C., and Oliver, D.M. (2017) Predicting diffuse microbial pollution risk across catchments: The performance of SCIMAP and recommendations for future development. *Science of the Total Environment* 609, 456-465, doi:10.1016/j.scitotenv.2017.07.186. (*9 citations*)

4. Details of the impact

The use of SCIMAP is transforming practice by a wide range of stakeholders at the interface between catchment science and management. This impact stems directly from the emphasis in the underpinning research on rapid estimation of relative risk at scales that are directly relevant to stakeholders. Rather than generating a single 'solution' or trying to account for all aspects of

catchment management, SCIMAP instead provides a flexible, accessible way of visualising the problem. Thus, the usefulness of SCIMAP has been primarily in providing evidence and fostering engagement and conversation between regulators (such as the Environment Agency), landowners (including both individuals and institutions like the National Trust), knowledge intermediaries (such as the Rivers Trusts), and tenants and land users.

Impacts arising from the use of SCIMAP for catchment management were submitted by Durham University as an impact case study for REF2014. Here, we claim only those impacts from the use of SCIMAP that go beyond those original impacts, and that have arisen since 1 August 2013. These impacts can be divided into three main thematic uses of the software, which we describe in turn below.

Theme 1: Providing evidence of existing issues
SCIMAP has been widely used to provide evidence of diffuse pollution issues that can build consensus among stakeholders and to target specific interventions. This impact has primarily been realised through Rivers Trusts (RTs), which are charitable organisations that make practical, evidence-based catchment improvements and serve as key knowledge intermediaries between landowners, regulators, and river users across the UK (evidence source **E1**, 12:15 to 12:42). The initial impact of SCIMAP during the REF2014 period was on ten of the larger and more technically able RTs, primarily the Eden, Yorkshire Dales, and Westcountry RTs. Within the REF2021 period, however, SCIMAP has become a standard tool for catchment management across all 46 RTs in England and Wales (**E1**, 00:16 to 01:41). This expansion has coincided with growth in both the importance and capacity of the RTs and an increasing emphasis on their use of scientific evidence for decision making. As summarised by a senior specialist in GIS and data management at the Rivers Trust parent organisation,

'…SCIMAP has been integral to the growth of the use of data and evidence in catchment planning… We also increasingly take a whole catchment view and plan where we're going to work based on priorities. So it's about prioritising fieldwork… But it [SCIMAP] helps you decide where you go and do that fieldwork and where you put the measures.' (**E1**, 00:48 to 00:56 and 03:21 to 03:40)

Similarly, a senior manager of the Ribble RT argued that

'from early days it's been helping us to focus where we want to work and then expanding that to then saying … "this catchment has a significant risk score so we want to focus our work in this catchment" and then drilling down and then actually sharing that information with the farmer. And that evidence. And demonstrating to all that we are evidence-led… And I think other Rivers Trusts need and are moving towards more that way.' (**E2**, 04:13 to 05:00)

SCIMAP has also become a key modelling tool within the Catchment Partnerships in all 100+ catchments across England and cross-border with Wales as part of Defra's Catchment-Based Approach (CaBA) programme, which began in May 2013. CaBA is an innovative framework for collaborative catchment management and improvement that directly supports delivery of the Government's 25 Year Environment Plan and includes more than 1,500 organisations. The CaBA programme advocates the use of SCIMAP as a risk modelling tool in preparing a catchment management plan (**E3**) and provides case studies of how SCIMAP can be used, for example to support and inform farm advice visits (**E4**).

Theme 2: Risk assessment
A second major area of impact has been via the use of SCIMAP to assess erosion and diffuse pollution risks at both the whole-catchment and farm-specific scales. For example, the National Trust is using SCIMAP to identify erosion risk and fine sediment connectivity across all 41 catchments in its northern region, and to produce catchment management plans for circa 10 catchments nationwide as part of the Riverlands project. The National Trust is the largest private landowner in the UK, with holdings of 250,000 hectares (ha). SCIMAP provides detailed evidence of erosion potential, enabling immediate mitigation actions such as tree planting or closing areas to the public – for example, across 30 National Trust properties in the Lake District after Storm

Desmond in 2015 (**E5**, 05:55 to 07:28 and 11:49 to 13:46). It is also used to facilitate discussions with tenants, in order to achieve the Trust's goals of linking land and water management and ensuring that water leaving Trust land is better quality than when it enters. As stated by a senior land manager at the National Trust,

'SCIMAP is proving quite useful to those property teams. It's picking up erosion risk, it's picking up surface connectivity and it's also picking up fine sediment… As a practical tool, SCIMAP has been absolutely brilliant in terms of the fact that it's so easy for property staff, the operational staff… at our properties to (a) get hold of and (b) then… evaluate their own properties against it with their own knowledge.' (**E5**, 06:49 to 07:04 and 19:21 to 19:51)

Similarly, SCIMAP is available on the Environment Agency central modelling platform for use by land-use modelling specialists across all 26 administrative areas in England and Wales. SCIMAP is the only software tool on the platform for tracking both sources and connectivity of diffuse pollution and fine sediment in river networks. A senior specialist in agricultural risk and evaluation at the Environment Agency argues that

'…a lot of the tools I was familiar with much more standard, you know, water quality models which I didn't think were appropriate for an agricultural programme like CSF [Catchment Sensitive Farming]… Once you know there is a problem ... then it's very much about what you then do about it. And it's a very good tool for testing those things out.' (**E6**, 01:10 to 04:04)

Natural England has used SCIMAP to improve the management of freshwater Natura 2000 sites within England. The Natura 2000 network covers valuable and threatened habitats across Europe, and England has 338 Natura 2000 sites that cover more than 2,000,000 ha. Before the REF2021 period, Natural England carried out the first national strategic prioritisation exercise of the whole Natura 2000 network, published in May 2013, and importantly identified the need for evidence of improvements that could result from various interventions. During the REF2021 period, SCIMAP was used between October 2014 and May 2015 to create a Diffuse Water Pollution Plan and Action Plan for every freshwater site (see, for example, **E7**), and is the only model that provides risk maps that cover both pollution sources and connectivity. The Westcountry RT was commissioned by Natural England to model fine sediment erosion risk in the 31 catchments that cover all the Natura 2000 sites. That study found that

'erosion risk and in-channel concentration risk maps generated [by SCIMAP] … provide an invaluable component of evidence to support the on-going development of the Diffuse Water Pollution Action Plans.' (**E8**)

As an example of SCIMAP impact on a commercial firm and across different national contexts, Environment Systems Ltd. is using SCIMAP to map environmental pressures and provide evidence to decision-makers at the national scale in Wales, St Helena, and the Caribbean British Overseas Territories (**E5**, 25:27 to 33:09, 33:10 to 38:19, and 38:20 to 50:11). In Wales, Environment Systems Ltd. has used SCIMAP to produce reports for the Welsh Government on risks and opportunities around the sustainable management of natural resources. These reports, known as Area Statements, are mandated by the Environment (Wales) Act 2016 and underpin the National Development Framework, the national-scale strategic development plan for Wales for 2020-2040. SCIMAP outputs provide evidence of flood and erosion risk in three of the six priority areas (natural flood management, water quality, and food). In St Helena, SCIMAP estimates of the spatial pattern of erosion risk have been provided to the Government of St Helena, along with opportunities for erosion risk management by replanting native vegetation. In the Caribbean, Environment Systems Ltd. has used SCIMAP to assess erosion risk before and after recent hurricanes, to identify the sources of damaging inland flooding, and to recommend mitigation measures for key infrastructure to the governments of Anguilla, Turks and Caicos, and the British Virgin Islands. As stated by a senior director of Environment Systems Ltd.,

'SCIMAP is great because it's one of those things that you can put a map of the erosion risk and people get it. The policy-makers understand it, and they can see immediately that that's giving them

evidence that they can go and take to developers and other people to help with their land use policies.' (**E5**, 21:44 to 22:04)

Theme 3: Enabling communication and engagement
The final way in which SCIMAP has had impact is by enabling communication and engagement in land use and water quality issues across a wide range of different stakeholder groups. This has developed in diverse ways across the RTs: for example, visits by the Wye and Usk RT farm advisors to discuss issues and specific advice plans with farmers (**E1**, 15:37 to 17:46), conversations between the Trent RT and a major landowner around river management (**E1**, 25:22 to 26:26), discussion between the Ribble RT and Hyndburn Borough Council to identify sites for woodland planting to maximise the benefit of investment (**E5**, 53:11 to 54:05), and collaboration between the Westcountry RT and South West Water to identify sites for flood management (**E5**, 1:12:30 to 1:14:00). The senior specialist at the Environment Agency argues that

'SCIMAP is a really good way of breaking down barriers. It's a fantastic way to start a dialogue… You're taking what… can be quite complex hydrological processes and presenting it in a very graphical and easy to understand way.' (**E6**, 06:12 to 07:01)

Similarly, the senior manager at the Ribble RT found that 15-20% of farmers engaged by the RT had asked for SCIMAP products:

'The [SCIMAP] outputs could be shown to farmers to show them that we have evidence that there are high risk areas of pollution and then we could ground truth that alongside them… And we were able to work with some of them constructively to implement change.' (**E2**, 00:46 to 01:25)

Critically, SCIMAP provides a platform for integrating that engagement, so that RTs can engage with farmers once through dedicated farm advisors, rather than through multiple visits by different project officers and specialists who are concerned with separate aspects of the catchment (**E2**, 07:14 to 09:50).

5. Sources to corroborate the impact (indicative maximum of ten references)

E1: Video of 2016 SCIMAP User Group Meeting, London, 18 October 2016.

E2: Audio interview with senior manager, Ribble RT, 11 March 2019.

E3: CaBA (2016) A Framework for a CaBA Catchment Management Plan, December 2016.

E4: CaBA (2018) The Cycle of a Farm Advice Visit, July 2018.

E5: Video of 2018 SCIMAP User Group Meeting, Birmingham, 26 September 2018.

E6: Audio interview with senior specialist in agricultural risk and evaluation, Environment Agency, 21 March 2019.

E7: Natural England (2015) River Wensum SSSI – Exemplar Diffuse Water Pollution Plan and Action Plan.

E8: Natural England (2015) SCIMAP Sediment Risk Mapping for Designated Site Catchments.