

Whitman GP, Pain R, Milledge DG.

[Going with the flow? Using participatory action research in physical geography.](#)

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Abstract

This paper critically appraises the idea and practice of 'participation' in scientific environmental research, arguing for the wider uptake by physical geographers of Participatory Action Research (PAR). PAR offers an alternative approach to science, involving the co-production of an open research process by local stakeholders or activists, through every stage from question definition to outcomes. We begin with a critical review of public participation in environmental research and policy-making to date. We argue that much rhetoric and practice of participation is relatively shallow, focusing narrowly on including relevant publics and stakeholders without granting them substantive input, or on building trust in science or policy-making rather than reshaping agendas to reflect public concerns. This is a stark contrast with the radical traditions in which participatory research and planning originate. We then report on a collaboration between academic researchers and a UK Rivers Trust, in which we used PAR to research farm slurry pollution, discussing and evaluating the research process. We argue that PAR not only has the potential to result in enriched and innovative science relevant to pressing environmental problems, but that it provides a more democratic and equitable approach than conventional academic and policy structures allow; PAR can thus present a valuable approach for future physical geography research. Nonetheless, a number of barriers to deep participatory processes need to be addressed if this way of working is to become mainstream.

Keywords Participation, participatory action research, co-production, knowledge hierarchies, catchment management, critical physical geography

I Introduction

In recent years, participation in environmental research and management has received a great deal of attention, partly prompted by policy imperatives, and partly by changes in the funding and evaluation of science. These trends contain contradictions and tensions. On the one hand, the rise of action-oriented approaches has led to a growth in engagements and alliances between academics and outside organisations and activists, particularly on issues of social and environmental justice (Chatterton et al., 2009; Kindon et al 2007). On the other, the state is demanding more accountability and impact on the real world from academics. This trend has been manifested in funding requirements and research audits in a number of countries now requiring user or public engagement, but defining engagement or impact in ways that privilege collaborations with high-level research users rather than, for example, community organisations or activists whose work might be more radical (Pain et al 2011). This interest in participation has included those physical and environmental geographers working on relevant topics who may seek to have research impacts, practice methodological or interdisciplinary innovation, or whose fields require collaboration with non-academics (e.g. Blackstock et al., 2012; Chilvers, 2008; Lane et al. 2011). In the social sciences, participation in all its guises has transformed from marginal interest to a central plank of concern. We argue in this paper that a more widespread engagement can also benefit physical geography research agendas and processes.

Participatory Action Research (PAR) has seen a growth of interest in critical human geography (see Kindon et al., 2007), and has great potential as a framework within which scientists may collaborate with those directly affected by environmental issues to

co-produce knowledge. It is thus a research approach that can be applied to many of the issues of interest to physical geographers. Among these, it lends itself well to forwarding the agenda of critical physical geography (CPG) set out by Lave et al (2014; and this issue). The central focus of the CPG agenda is to attend to the co-production of socio-ecological systems and processes through recognizing the impracticality of separating social and natural sciences and their mutual roles in social transformations (Lave et al 2014, p. 6). Specifically, this agenda asks that researchers from within critical human geography as well as physical geographers from a broad range of disciplinary perspectives actively address and acknowledge the interrelationship between power relations, multiple knowledges, biophysical sciences and how these impact on socio-ecological environments (Lave et al., 2014). We suggest that PAR is well suited to both contribute and expand on this agenda, for the following reasons.

Firstly, its originators in critical pedagogy have actively advocated and practiced community engagement in a wide range of social but also environmental contexts (Fals-Borda 2002; Freire, 1973; Fine et al., 2007; Kindon et al., 2007). In PAR there is recognition that power relations are vital to understanding the interrelationship between social and environmental contexts. Secondly, as a 'philosophy of research' rather than a specific methodology, multiple social and natural science methods may be adopted in PAR in order to address social and environmental issues (Fine et al., 2007). Finally, PAR is a more radical and comprehensive approach to the co-production of knowledge than many other approaches to socio-ecological issues. PAR works from the principle that those directly affected by the issue at hand should be involved in the construction and analysis of research from the beginning. Further, PAR provides a well-established set of processes that help to circumvent the common ethical and

political tensions around the relevance and ownership of scientific research and policy-making, by challenging when and by whom research questions are formulated, who has the right to produce knowledge, and who owns and benefits from its outputs and outcomes. It is a challenge to issues of power and ownership in research: but this need not, we go on to argue, conflict with or undermine the details or rigour of scientific method.

Informed by the roots of PAR in radical social theory and activism, this paper therefore critically appraises the idea and practice of 'participation' in scientific environmental research. As Wynne (2007, pp. 219-220) has noted, there is an 'intrinsic futility' in trying to produce public trust in science if the objective of this is to 'manage and control the other's response'. Approaches to participation that are driven by an underlying rationale of creating better science by involving members of the public in *pre-determined* scientific research are limited in their ability to succeed. Like Lane et al. (2011), we suggest that if the scientific method is removed from its traditional hierarchy of expertise, and scientists work with others in collaboration, research may become more democratic and innovative. PAR is not in conflict with science: instead, it offers 'an alternative mode of public science which commits at once to human rights, social justice and scientific validity' Torre et al. (2012, 182). Rather than attempting to undermine or dismantle the expertise of scientists within the research process, PAR processes recognize that expertise can be certified in multiple ways, challenging forms of public participation that pre-determine which kinds of knowledge are relevant and useful (Wynne, 2007).

The structure of the paper is as follows. In Section II, we review public participation in scientific research, identifying limitations in the way it has frequently been used, in particular that it often involves relatively shallow participation that does not address issues of ownership or power in knowledge production. We review the imperative for participation in the context for our research (catchment management), and introduce the tenets of PAR as an alternative research approach. In Section III, we report on a case study that illustrates PAR in practice, outlining a methodological process where questions were generated collaboratively, and which took an unexpected direction, leading to the co-production of a model for farm vulnerability to slurry pollution. As this was an experimental use of PAR in physical geography, the research process was evaluated through a series of group discussions and in-depth interviews with each participant conducted separately by one of the academic researchers, and we draw on this material as the paper proceeds. We conclude, with some provisos, that PAR has the potential to result in enriched and innovative science that is relevant to pressing environmental problems, and provides a more democratic and equitable way of doing so than conventional academic and policy structures tend to allow.

II The imperative of participation in science: a critical view

1 The call for public participation

Public participation in the governance of science and in wider decision-making processes concerning the environment is now firmly established as a key imperative within both academic and policy discourses and practices (Felt and Fochler, 2008;

Irwin, 2006). Within the UK a series of policy documents make explicit the need for public involvement and dialogue with science and scientists (e.g. DTI, 2003; House of Lords Select Committee on Science and Technology 2000; Royal Commission on Environmental Pollution 1998). Such public participation has variously been promoted on normative grounds (i.e. people's right to participate in democratic decision-making processes), substantive grounds (that higher numbers of participants make for better decisions) and instrumental grounds (participation increases the legitimacy of the policy-making process) (Chilvers, 2008; Reed, 2008; Wynne, 2006).

This 'rhetorical shift' (Irwin, 2006, p. 300) within UK policy discourse on participation came in reaction to a 'crisis of legitimation' in policy circles during the era of the deficit model¹ of science when publics were largely excluded from such deliberations (Irwin, 2006; Chilvers, 2008). There is a recent effort, then, to restore public trust through participatory processes so that scientific developments can proceed through broad social consensus. However, this agenda of building 'trust' in science or policy among the public, rather than addressing the issues and concerns of those non-academics affected by a particular issue - can be problematic. Specifically, it continues to support a knowledge hierarchy where science is elevated above other forms of knowing. Any public doubts about the validity of scientific knowledge is often attributed to ignorance about the issue or about the science, rather than as a legitimate contestation based on alternative ways of knowing (Callon 1999; Jasanoff, 2003; Wynne, 2003; 2007). This can lead to instrumental approaches to participation that aim at the education and

¹ The 'deficit model' of science essentially argued that public skepticism of science was due to their 'illiteracy' concerning scientific knowledge. Emphasis was placed on 'educating' the public about science in the belief that this would increase public support and confidence in both science and scientists (Wynne, 1991)

inclusion of publics into existing approaches to environmental management that have already been decided. Alternative approaches that question the prioritization of any one set of knowledge, and work together to reconstruct it, are extremely rare. In other words, local expertise may now inflect solutions, but rarely informs the setting of priorities of questions in scientific research or policy-making.

The participation of publics in environmental research or management is often bundled together as a homogenous enterprise, but in fact includes a very diverse range of approaches (see Phillipson et al., 2012). Participation is a highly contested term, and there is no agreement about how to incorporate it into research or management, or even why this should be done. However, scholars have tended to focus on two key facets of participation: degree and quality. The degree of participation reflects issues such as duration of involvement, numbers and diversity of participants, or the power that participants have over the research process (Shirk et al., 2012: p. 3). In contrast, the quality of participation reflects the extent to which project goals align and respond to those of the public participants (Shirk et al., 2012, p. 3). This diversity is no surprise, given that the conceptual and practical development of participation has taken place in multiple disciplines for multiple purposes, including grassroots activism in education (Freire, 1972); resilience thinking (Gunderson and Holling, 2001); sustainability science (Clark and Dickson, 2003); Science and Technology Studies (STS) (Collins and Evans, 2002; Jasanoff, 2003; Wynne, 2003); psychology (Torre et al., 2012) and geography (Kindon et al, 2007). 'Participation' has thus become imbued with numerous ideological, methodological and political meanings (Lawrence, 2006).

Calls for increased participation of publics in the governance of science, as outlined above, also reflect the increased importance of co-production in such governance. This is reflected in Callon's (1999, 85) model of the co-production of knowledge, where he argued that non-scientists (i.e. lay people and communities) have 'specific, particular and concrete knowledge and competencies' with an important role to play in enhancing the abstract knowledge of scientists. For Callon (1999) it was the combining of these two types of knowledges that leads to deeper understanding of scientific issues. Callon's model remains much cited, but rarely achieved in practice. However, any move towards a more co-produced model of participation must address questions of ownership and power, such as who should and should not participate, in whose interest, and - most importantly - for whose benefit? While these questions are well rehearsed in human geography and STS, even in these disciplines much participatory research falls short of the ideal (Delgado et al, 2010; Felt and Fochler, 2008; Kindon et al., 2007). Academic and policy literatures typically frame the choice among the various available approaches to participation as a choice about appropriate *methods* for enquiry (Oliver et al. 2011; Rowe and Frewer 2005).

However, in order for participation to become more aligned to co-production it is necessary to move beyond simply working with innovative methods in environmental research such as citizens' juries and panels, consensus conferences, focus groups, round table discussions and citizens' panels (O'Neill, 2001, et al., 2003; Owens, 2000; Frewer and Rowe, 2005). Such methods maintain a conventional approach to research where the academic researcher sets the agenda and controls the research process. This leaves the importance of power relations and whose knowledges should be involved in the research process unchallenged.

2 Participation and catchment management

Catchment management is an area in which participatory imperatives and approaches have burgeoned in recent years, yet understandings and practices have tended to centre on conservative approaches rather than fuller models of co-production, where project goals and outcomes are shared. Demands for public participation in environmental issues are especially resonant within recent European water legislation (Chess, 2000; Carter and Howe, 2006): the 1998 Aarhus Convention required that measures are taken to include public participation approaches during the preparation of plans and programmes relating to the environment (Carter and Howe, 2006). The resulting Water Framework Directive (WFD) (2000/60/EC) was one of the first pieces of European legislation explicitly demanding a high degree of involvement of non-state actors in implementation (Newig *et al.*, 2006); any person, group or organisation with an interest or stake in an issue, either because they will be directly affected or because they may have some influence on its outcome (Newig *et al.*, 2006). The WFD therefore reflects Pretty and Hine's (1999, cited in Carter and Howe, 2006) suggestion that the complexities of real-world problems need solutions that are developed by all stakeholders, and signaled a new approach in which stakeholders were to be more closely involved in the management of water resources (Carter and Howe, 2006). In the UK, River Basin Plans are under the jurisdiction of the Environment Agency (EA). Here the EA has been involved in trialing innovative approaches to their management through novel forms of engagement with people and organisations at a catchment level to improve the health of water (<http://www.environment->

agency.gov.uk/research/planning/148309.aspx). However, despite numerous catchment-related projects, concerns have continued to be voiced that participation in such projects has not achieved the ideals of co-production resulting in the issues of power and ownership identified above being left unchallenged (Maynard 2013; Petts 2007; Pahl-Wostl et al., 2011). Most participatory initiatives in catchment management are still organized or at least heavily influenced by those considered to be experts such as scientists (both natural and social), non-government agencies (NGOs), statutory bodies or government, rather than those who live and work in the affected areas (Cook et al., 2013).

3 An alternative approach: Participatory Action Research (PAR)

From its early origins, PAR has been founded on community-based research processes that support people's participation in knowledge production and social transformation (Fals-Borda 2006; Freire, 1973). PAR has diverse origins, but many date it back to the work of the radical emancipatory educator Paulo Freire (1973), who emphasised mutual learning and the development of 'conscientization'² as a catalyst to transform lives and situations through political action. This inspired a 'new epistemology of practice that was grounded in people's struggles and local knowledges' (Kindon et al., 2007, p. 10), which quickly spread within Africa, India and Latin America, and later to North America and Europe. PAR is distinct among participatory approaches as it offers a democratic model of who is able to produce, own and use knowledge; it is driven by

² The term 'conscientization' is a translation of the Portuguese word *conscientização*, which means 'consciousness raising' or 'critical consciousness'.

participants (people who have a stake in the issue being researched) rather than an outside sponsor, funder or academic (although they may be invited to help); it is collaborative at every stage, involving discussion, pooling skills and working together; and it is intended to result in some action, change or improvement on the issue being researched, towards more socially and environmentally just outcomes. PAR has been used, for example, to research environmental issues by groups and communities who have often been marginalized in knowledge production processes (e.g. St Martin and Hall-Arber 2008; Gavin et al 2007).

PAR has potential to both challenge and enhance science through a philosophy that contests socially inequitable participation processes. It 'deliberately invert[s] who constructs research questions, designs, methods, interpretations and products...[so that] the traditional objects of research reposition as the subjects and architects of critical inquiry, contesting hierarchy and the distribution of resources, opportunities and the right to produce knowledge' (Fine et al. 2000). We suggest that PAR can potentially bring scientist and non-scientist stakeholders and/or activists together to formulate research agendas that are scientifically rigorous, democratic, and also address policy concerns. This is not to say that PAR is always successful in tackling knowledge hierarchies, nor that it has not been open to subversion by more powerful groups or interests (Cooke and Kothari, 2001; Kindon et al.,2007).

Nonetheless, PAR offers not only co-production that is compatible with the vision set out by Callon (1999), but a model by which participants drive and have ownership at all stages of the research process. Physical geography and related fields in western science have seen recent expansion of participatory approaches and techniques (e.g.

Blackstock et al., 2011; Bracken et al., 2014; Forrester et al., under review; Lane et al., 2011; Selman et al., 2010) and a recognition that participants value research projects in which their interests and concerns are included from the beginning (Bracken et al., 2013). Generally, speaking, however - and this is reflective of environmental research more widely - the use of participatory *methodologies* that engage publics and stakeholders at the data collection and/or verification stages is far more common than participatory *approaches* where academics co-research alongside others as equal partners through the entire research process. Lane et al. (2011) are perhaps best known for pushing participatory approaches in the discipline to date; our study and focus on PAR, an established approach in critical social science, builds on their work and takes this effort further.

III Using Participatory Action Research in practice: a case study of farm slurry pollution

In this section we illustrate the use of PAR to develop and conduct a research project in physical geography. We suggest that its use enriched and enhanced the scientific outputs, as well as framing a more democratic model of knowledge production. The project was a collaboration among three academic researchers and members of the Lune Rivers Trust (LRT) in north west England. The three authors of this paper are the researchers who were actively involved in the field research; Dave (a physical geographer with interests in catchment hydrology and geomorphology), Geoff (an environmental social scientist) and Rachel (a human geographer with experience of using PAR with a wide range of public organisations, community groups and activists). The main aim of Rivers Trusts is 'to co-ordinate, represent and develop the aims and

interests of the member Trusts in the promotion of sustainable, holistic and integrated catchment management and sound environmental practices, recognising the wider economic benefits for local communities and the value of education' (<http://www.theriverstrust.org/about/>). We worked together over three months, meeting regularly, and all group members conducted 'homework' between meetings. Table 1 gives an indication of the broad stages of PAR processes. In this section, we discuss how we worked together to produce research questions, to select methods and conduct fieldwork and analysis, and to produce the project outputs.

Phase	Action
<i>Action</i>	Establish relationships and common agenda with all stakeholders.
<i>Reflection</i>	Collaboratively decide on issues On research design, ethics, knowledges and accountability
<i>Action</i>	Build relationships Identify roles and responsibilities Collectively design research processes and tools Discuss potential outcomes
<i>Reflection</i>	On research questions, design, working relationships and information required
<i>Action</i>	Work together to implement research and collect data Enable participation of all members Collaboratively analyse findings Collaboratively plan future actions
<i>Reflection</i>	On working together Has participation worked? What else do we need to do?

<i>Action</i>	Begin to work on feeding research back to all participants and plan for feedback on process and findings
<i>Reflection</i>	Evaluate both the action and reflection processes as a whole
<i>Action</i>	Collectively identify future research and impacts either with academics or alone

Table 1: Key stages in PAR (adapted from Kindon et al., 2007, p. 15)

1 Co-production of research questions: from verification to origination

This section explains how the research questions were developed collaboratively during the project, rather than being pre-determined by the academic partners, and evaluates the benefits of doing it in this way. From an initial plan to use the LRT members to verify findings, their role on the project was inverted and they originated the focus of the enquiry. In PAR, research questions are defined in this way by the ‘community of interest’ - those directly affected by an environmental issue - which may or may not include scientists.

Originally our project, which was UK Research Council funded, had already proposed broad research questions at the stage of funding application: the proposal stated that the issue at hand was diffuse pollution, and that the focus was to be on key organisations that were responsible for managing river catchments rather than local groups and communities directly impacted by the issues. It also proposed pre-determined methods of ‘model outputs on catchments’, with the non-academic participants’ role being primarily the ‘critical verification of science and management prescriptions’. It became clear, however, that this approach did not fit with the philosophy of PAR, specifically that it did not involve local participants in deciding what

the issues of concern were. We therefore began by working with LRT members to identify research questions and how we might go about tackling them. We facilitated these discussions using participatory diagramming techniques (see Alexander et al 2007). At our first meeting participants were asked to plot the most pressing issues on a map of the catchment (see Figure 1). The key issues were then debated and prioritised by the group using further diagramming techniques. Initially there were twenty-three ideas for research topics, and over four meetings these were subject to group reflection and background research both during and outside meetings; we asked whether each topic was urgent, feasible to research in terms of scope and timescale, and what existing knowledge was available. The decision-making process included consideration of the skills and expertise required for the research (discussed below), and any sensitive political issues (for the LRT, the issue of managing good relations with groups such as farmers and anglers was of particular concern). The research topic finally agreed through this process was slurry pollution of watercourses. Slurry is ‘a liquid or semi-liquid matter composed of excreta produced by livestock while in a yard or building’ ([The Water Resources \(Control of Pollution\) \(Silage, Slurry and Agricultural Fuel Oil\)\(England\) Regulations 2010 \(SI 2010/639\)](#))



Figure 1: Participatory diagramming of key issues in the Lune River catchment

The precise research question was not generated until the fifth group meeting. First, the group (academics and LRT members) conducted background research on slurry, to understand the nature of the problem experienced in the Lune catchment. By discussing this research the group came to a consensus on the role of slurry in reducing instream oxygen concentrations and its impact on the river as a whole. Here group members brought their own concerns to bear, especially the impact of bad weather and the Trust's experience of government policy:

LRT member: “Well when it’s spread and it comes thunderstorms and that it washes it off you know before it gets chance to sink into ground, that’s one of the worse”

LRT member: “And the nature of that means that they’re all doing it at the same time so you get a big flush rather than it being a continuous process”.

LRT member: “And...the government’s trying to come up with a thing where they’ve all got to put it on at same time - well that’s going to make it worse than ever because they’ll all be at it.”

The group was agreed that conducting joint research to tackle the issue would be helpful to their work to combat pollution. Once they made this decision, we examined a water quality model developed on one of Dave’s previous projects. This was to give the group an idea of what Dave had done in the past and what we might do on the Lune catchment. The group was critical of the model’s applicability to their context, as we describe in the next section.

But from this work, the research question for the main project arose. A group member suggested that we investigate whether some farmyards were more vulnerable to slurry pollution than others. The rest of the group agreed that it would be extremely helpful to know the location of potential problem areas in the Lune catchment where slurry would be at most risk of being washed from farm yards into rivers, and that this knowledge could help with early preventative action or the more targeted use of resources to tackle these issues. Dave had never considered this question before, but

he considered that a similar modelling approach could work for farm yards as it does for locations in fields.

Before we go on to discuss the rest of the research, we reflect on this process of developing research questions collaboratively with participants (as compared to beginning research with questions pre-determined by the scientific partners). As we have outlined, the process of narrowing down the topics and developing research questions was not straightforward or linear. Participants and academics had different experiences and expectations of how research normally functions. Some LRT members were confused at the start of the project as we explained our jettisoning of the original proposal and the plan to begin with a clean slate. One LRT member said in the first meeting:

“I haven’t grasped really what you want here...I’m baffled at the moment completely you know, and you’re on about four meetings, if I don’t get more understanding I wouldn’t be at the next one because I don’t know what you’re on about” (LRT member)

This was a view that initially was held by a number of others. A second reason for the confusion was the novelty of PAR with its emphasis on co-production. As a Rivers Trust, participants had been involved in a range of research projects, but usually working on someone else’s research as subjects:

LRT member: We’ve got another project ongoing with...somebody from...University but that’s very specific research.

LRT member : He’s come to us really.

LRT member : He's come to us, he's doing this, which is fine you know and that's how it would normally work.

Geoff: Right and that suits your needs as well?

LRT member : Well we're just facilitating his research.

However, as our meetings progressed, opinions changed:

Rachel: An alternative would be that we'd come to you...and said "this is what it's going to be about", that would have been the alternative.

LRT member : This is definitely better, this process.

LRT member : Definitely.

LRT member : Yes.

In exploring why the PAR process was perceived to be 'better', a number of important issues were raised. Firstly, as a group there was a sense that often research is imposed on them by outsiders - although they willingly take part, they know they are 'working for others' rather than 'working with others':

"I felt was that instead of somebody coming along and saying this is what we're going to do, *we decided what we wanted you to do* and that's pretty unusual so we weren't being forced to accept something" (LRT member) (emphasis added)

The extended and at times frustrating process of narrowing down areas of interest into a set of research questions was eventually viewed as very productive, raising critical

debate and discussion about the group's priorities that, in this case, also had benefits for their wider work. The time spent having these initial discussions, if facilitated carefully, can also create a positive group dynamic and an atmosphere in which participants feel that useful outcomes from the research are more likely to result. It also created space for the non-academic members of the group to question the areas and extent of the expertise of the academics, and clear mechanisms to feed their own expertise into the investigation.

Developing the focus for research with participants is also a challenging prospect for scientists, given the usual expectations governing research projects. Rather than present a general truism that this always makes for better science, we suggest that it can enrich science in certain contexts, especially where local knowledge may produce innovation in the questions asked, processes followed, outcomes and their impacts, as we have described on our project. At the same time, for academic researchers, PAR is challenging: it draws on social and emotional as well as technical skills, involves letting go of control of knowledge production, and placing trust in the new process and in other participants. Geoff, the academic partner who had no previous experience of using PAR described it as '*an emotional rollercoaster*', but felt that the eventual positives far outweighed the initial discomfort. For Dave, the physical geographer, the approach to developing research questions was also challenging at times:

Dave: "One of the things that I almost personally I've found more challenging is that you go into a meeting not knowing what the agenda's necessarily going to be, and what the questions might be that come out that, you're much less in control of the agenda which means that you are much more quickly, I'm much more quickly outside

my comfort zone”.

2 Co-production of methods, fieldwork and analysis

PAR is an approach based on a set of core values and a broad process of knowledge creation, rather than specific methods. As such, once questions have been decided, methods are selected from already existing social and natural science approaches (Kindon et al., 2007). Together, project teams work iteratively to develop data collection and analysis, sometimes dividing up tasks according to experience, making and reconsidering decisions together, and proceeding through cycles of action and reflection (see Pain et al. 2012). While this approach might at first appear to be a poor fit to the usual scientific research process, we suggest that it does not fundamentally alter the scientific method: rather, this approach is developed and discussed by ‘uncertified’ as well as ‘certified’ scientists (Lane et al., 2011).

Throughout our project, but especially in the early stages, social science methods (participatory diagramming) helped to frame, organise and make collective decisions. The main methods for our research project on slurry risk were vegetation surveys, modelling and mapping. In part these methods reflected the skills and competencies of the academic members of the group, but they also engaged the different skills and competencies of the members of the LRT, who had backgrounds ranging from medicine, chemistry and ecology through to extensive local knowledge of the ecological and social history of the river catchment. Members brought experience of surveying flora and fauna, and understanding of the various inter-connected policy and

funding frameworks that affected their catchment. Their long association with catchment helped them to decide what would 'work' there.

To investigate the controls on slurry pollution in the Lune catchment, the group first applied SCIMAP (Lane et al., 2006), a risk based diffuse pollution model already known to some members of the Trust. For every location in the catchment SCIMAP predicts an availability risk, based on land cover; and a delivery risk, based on the probability of a saturated flowpath to the river. These risks are then combined to predict the locational risk, the joint probability that a pollutant (e.g. slurry) is both available in a location and that it can be delivered to the river network. However, the proposed switch of focus to farmyard vulnerability meant that SCIMAP's usual availability risk would no longer be a function of land cover and therefore could not be easily ascertained. However, Dave felt that SCIMAP's treatment of delivery risk remained relevant as a simple topographically based predictor of the relative risk that slurry, if present at a given location, might reach the river network. The important distinction from SCIMAP is that this approach makes no attempt to predict availability of slurry in a farm yard, something likely to be strongly dependent on local factors. Instead it predicts the vulnerability of the farmyards in terms of the risk that if slurry were to be available it might be washed into the river.

Dave brought SCIMAP to the next meeting and began to explain how it worked and what we might do with it. After working to create this tool both during and between meetings, we produced a series of maps that highlighted relative vulnerability of farmyards within the Lune river catchment (see below). These had been analysed and refined by the whole group. This process of co-production enriched

the knowledge that was produced in many ways. We report here two examples from different points in the project where unique knowledge was produced through the specific approach to collaboration that PAR offers.

Snapshot 1: Critiquing and re-orienting the model parameters

On first using SCIMAP, almost immediately the group began to critique it on the basis of their working local knowledge of what was being mapped. This questioning changed the parameters and processes of the methodology, and resulted in what we argue is more robust model. To help the group to understand how SCIMAP worked we engaged in a practical exercise in which the non-academic members of the group defined the availability risks that they would associate with different land covers (e.g. rough grass, arable, improved grass) as outlined in the Centre for Ecology and Hydrology's (CEH) land cover maps (<http://www.ceh.ac.uk/accessinglcmdata.html>). The group was very uncomfortable assigning a risk to the 'improved grass' class. This class is distinguished from semi-natural grassland based on its higher productivity and is classified based on its reflectance in remotely sensed images (Fuller et al., 2002). However, the group's experience in the catchment suggested that it contained too wide a range of land management practices (some are more similar to arable land in terms of fertilizer treatment, some more similar to rough grazing):

LRT member: "So what does 'improved pasture' actually mean? You see that won't work here because improved pasture as it is described here actually covers lots of radically different management practices."

These different management practices have different implications for the availability of nutrients that might be subsequently mobilized by surface or subsurface flow.

Therefore the group suggested splitting 'improved grass' into two categories: silage and permanent grazing, and assigning 'lower' risk to permanent grazing and 'higher' risk to silage and maize fields. However, this was not possible using existing data and new data would be very difficult to collect since similar reflectance for silage and permanent grazing fields makes them indistinguishable in most remotely sensed images. The group was then concerned that this might make SCIMAP unsuitable as a tool for identifying areas of the river where the risks related to slurry were highest. To test this we compared SCIMAP predictions using the CEH data with those from a field-by-field classification performed by local LRT members between sessions. The closer the two classifications were, the greater confidence the group would have in SCIMAP's predictions. To do this, LRT members walked the Cant Beck sub-catchment identifying maize, silage and permanent grazing fields (see Figure 2) on 1:25,000 scale Ordnance Survey base maps using the colour scheme outlined below.

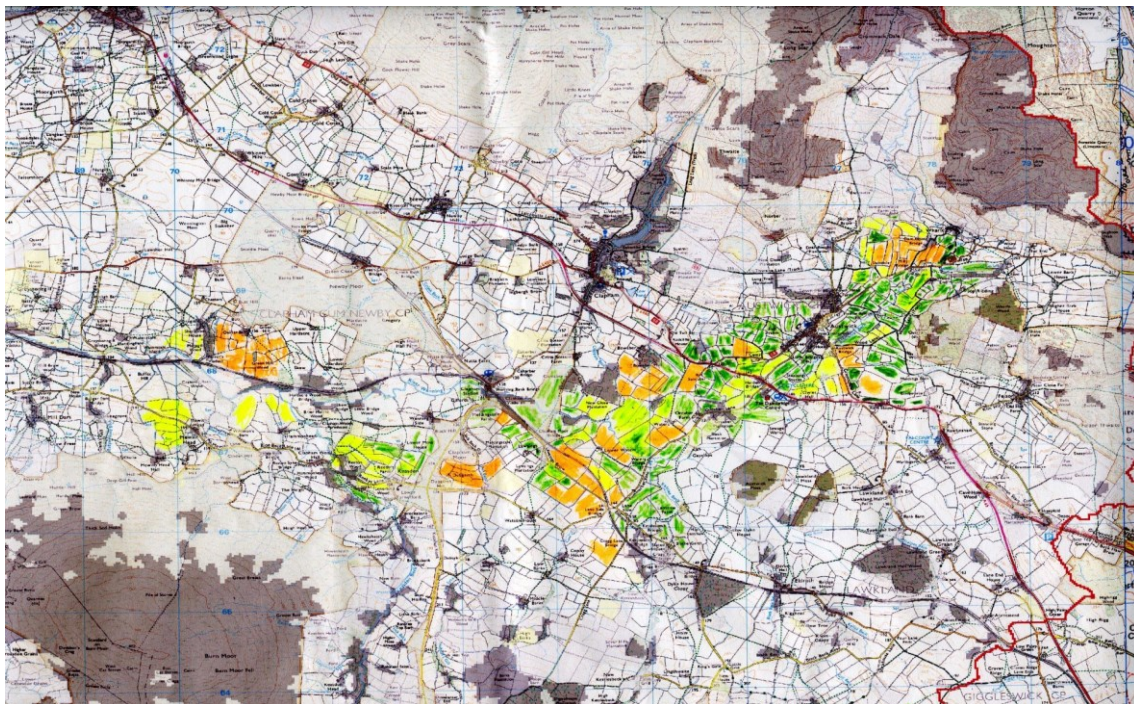


Figure 2: Improving SCIMAP land cover map through local knowledge. The map shows: silage fields (orange), permanent grazing (green) and improved grassland (yellow). Grey areas are rough grassland. The Ordnance Survey base map used here is reproduced by permission of Ordnance Survey on behalf of HMSO. © Crown Copyright. All rights reserved.

We collated this information at the next meeting and ran SCIMAP using the new land cover map and the land cover to risk relationships that the group had chosen for at an earlier meeting. The results showed 1) general agreement between predicted instream risk from the two land cover maps with higher (2nd and 3rd) order streams relatively insensitive to the different land cover classifications; but 2) some areas with large differences, generally for low 1st order streams draining areas covered by predominantly or exclusively improved grassland. This process gave LRT members confidence in their own risk classifications and a sense of how these matched up with those used within SCIMAP. This exercise was critical for building confidence among LRT members, both in their ability to critique model parameters that they felt were insufficient for their own purposes, and in their own knowledges which were vital in highlighting the weaknesses in model parameters and how these might be improved to better suit the particular needs of the research team. The research focus for the group moved from fields to farm yards and as a result the limitations on SCIMAP associated with a reliance on available land cover classes were not pursued. However, this interaction highlighted to Dave the need for improved land cover data to drive SCIMAP, identified exactly where that need was most pressing (in disaggregating the improved grass class) and affected Dave's interpretation of his own data on another project (Milledge et al., 2012). The problem of how to collect land cover data that is relevant to the nutrient availability in each field but feasible over very large catchment areas remains an open question.

Snapshot 2: Developing the model and ground-truthing farm vulnerability maps

One of the key coproduced outputs of this project was the Farm Vulnerability Tool (FVT). This was initially conceived out of the process of testing SCIMAP outlined above. The question of whether SCIMAP could be used to identify which farmyards were more vulnerable was not something that the academics in the group had thought of. If it worked, it would represent a fundamental change in the way the model was used, and would also show how powerful local knowledge can be in disrupting what can be known through a conventional scientific approach alone. It was decided that we should create a local example first to help think about how it might work. The group decided they wanted to take this forward and asked if we could bring a version for the entire catchment to the next meeting (see Figure 3).

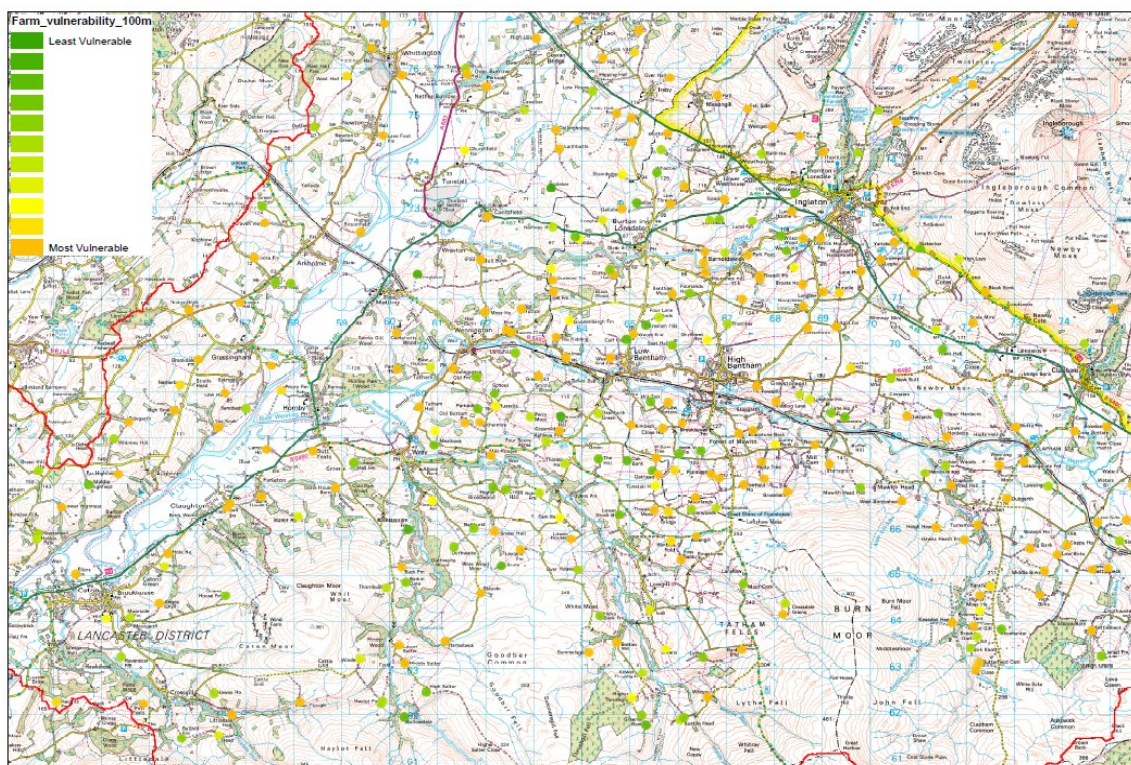


Figure 3: Part of the Farm Vulnerability map for the Lune Catchment The Ordnance Survey base map used here is reproduced by permission of Ordnance Survey on behalf of HMSO. © Crown Copyright. All rights reserved.

Having produced this map, we returned to the group and asked them to study the areas on it that they knew well. This process of ground-truthing proved invaluable. Using their local knowledge group members were able to highlight a small number of false negatives (farms that were not identified) and many false positives (locations mis-identified as farms because of changed use). With these errors removed the FVT could be used as screening tool to identify where to look first in spending time and money to reduce the risk that slurry from farm yards reaches the river network. The tool's predictive capability is difficult to test because it requires tracing material from farm yards into the river network. This is an area of ongoing research both for the LRT and the academic researchers.

On our project, the unusual combination of PAR and physical geography methods worked productively together. A key factor in this relationship was the way the non-academic members of the group associated with Dave, our natural scientist. In the evaluation stage of the project, a number of factors emerged that informed this relationship. Firstly, although overall the project team members and the process were well thought of, it was Dave's role as the natural scientist that stood out to many of the LRT members:

"I thought you were all brilliant, but Dave outstood to me way he put it across, do you know what I mean... And I learned, you know" (LRT member)

In particular, Dave's ability to communicate difficult ideas and concepts in ways that made them accessible and understandable to LRT members was considered to be one of the outstanding aspects of the project:

"The young lad that you had fascinated me, I thought he was brilliant way he described maps and the SCIMAP or whatever you call it, I thought he was brilliant...It were way above me in life you know, in that sort of field, and I thought it was brilliant way he put it over (LRT member)

Indeed, it has been noted elsewhere that the willingness and ability of natural scientists involved in an open-ended research project that is not necessarily framed by them is critical to the success of the kind of research described here (see also Landström et al., 2011). In turn, as PAR aims at a two-way process of knowledge production, Dave reflected on the value-added to his own practice as a scientist:

Dave: "I've come out of every meeting thinking 'that's food for thought' and...it's certainly informing my practice, in that I've written things over the last month or so where things that I've learned in the meetings have gone into journal articles...In terms of the science, there's something new in the farmyard index, it's kind of an outworking of that combination of...the modelling that we've done in Durham with this, the input from these guys."

3 Co-production of outputs

On many participatory projects, participation ends after the data collection or consultation stages, at which time those running the project (usually external

researchers) withdraw to make sense of and use the findings. A foundational tenet of PAR is that the knowledge produced is jointly owned, and any outputs and actions continue to be conducted by all participants. These may be diverse outcomes that suit the different audiences and users of research (Cahill and Torre 2007). In this case, the project outputs included a PAR toolkit which could serve as a guide for others wanting to follow the same research approach to environmental issues (Pain et al., 2012); a guide to the Farm Vulnerability Tool (Milledge et al. 2012) which explained the theory behind the tool and the limits of its applicability, with the aim of being transferrable for use in different contexts; joint conference presentations; and a final report. These have since been actively used in the LRT's work on farm vulnerability, informing funding applications, targeting of resources and practical work to reduce farm vulnerability to slurry reaching watercourses.

Again, co-production at this final stage allowed the pooling of a range of perspectives and skills. For example, the group felt that the Farm Vulnerability Tool, if it was to be re-used by the group and other users, required an easy to use guide to accompany it that would explain the concepts and methods. This then involved the scientists and social scientists working together, with feedback from the rest of the group, to ensure that a technical product was written in a way that was accessible to all. Equally, the final maps were assessed and road tested by the whole group, and revised accordingly to ensure that they would be useful and appropriate for all potential users.

The tools jointly produced with the LRT were directly relevant to what they needed for their work, and so were seen as immediately useful. In particular the farm vulnerability maps were seen as tools that not only addressed the specific issue for this research

(farm slurry), but that, thanks to the process of their production, could be broadened out to accommodate a wider set of issues for the LRT:

“It was interesting what Dave could do with the maps, with the system...Yes it just sort of reinforced to me what a great tool it is and it’s something that we need to get as a Rivers Trust” (LRT member)

One member of the LRT was already involved in a series of wider projects where the maps produced as part of this research were going to be used to inform wider projects throughout the Lune river catchment:

“I’m going to use something similar... I’m going to show them the map that Dave produced with the colours of the streams mapped on them... I’m not going to use an exactly similar process but I’m going to put the map on the table and say ‘your knowledge is greater than mine of each of these things, what are the key issues that we’ve got in there that we might think you know, that we can include and incorporate in the project above and beyond what we’re already looking at’” (LRT member)

A wider benefit of the PAR process for the LRT was the space it gave them to sit down together and reflect on the important issues facing the catchment, as well as techniques for working through issues and prioritizing actions:

“To tell you the truth I think as a group, without you, we haven’t sat down and really discussed that [the group’s priorities], and I think we’ve all got ideas of ways that we could carry it [the PAR process] forward and make it work” (LRT member)

“It’s unusual for so many people from the Trust to sit round a table and discuss ideas really” (LRT member)

“So...this process...it’s something that we can introduce into the Trust, have extra meetings just for brainstorming and something like that” (LRT member)

IV Conclusion

While many scientists and policy-makers have called for public participation in environmental research, our review at the start of this paper found that levels of participation tend to be fairly superficial. It is rare that local stakeholders and activists are involved in setting the questions and priorities for research, and feeding their local knowledge and understanding into the scientific processes. Participatory action research (PAR) presents an alternative model of doing science that allows such collaborations as outlined by Dave below,

“One of the things that I’ve always kind of thought about is that...my research agenda is basically needs driven, it’s driven by what the community, the scientific community, identifies as the current exciting piece of research or the current needs or the current gaps...and here it’s going to a different group of people and saying “what do you think’s interesting?” and then following that...If it doesn’t necessarily fit in that idea of what the scientific community considers an interesting question, then there might be quite a bit of friction in how that’s received...If you are trying to address something that people are concerned about, then there’s something valuable in the knowledge that’s driven that concern”

Dave makes an important point in the above quote about the potential “friction” that may occur for scientists being involved in such a research process. Specifically Dave is outlining that what is considered “interesting” research is often the product of multiple influences on a scientist (i.e. peer-group, funders, specific issues within a discipline and also local community concerns). Being part of a research process that uses PAR can bring in a wider range of interests and voices to bear on an issue, however, for a natural scientist a potential problem here is that this may dilute the interest that the wider scientific community had in this issue. In other words while such research brings recognition and credit from the local community for the role that the natural scientist played in addressing their issue this recognition may not translate across to the scientific community. Dave is thus making the important point that from a scientist’s perspective it is important that the issue that concerns the local community is also one that maps onto the broader interests of the scientific community.

Further, it opens up the question of who it is that defines what is relevant and interesting science, and who owns the knowledge that results. It helps to focus science onto locally important issues – a key issue for members of the Rivers Trust who, as the quote below shows, felt that national agendas do not sit well with priorities they see in their own catchment.

“The Rivers Trusts, if you will, are very much seen as a spending arm of DEFRA, and DEFRA may come along and say “well there’s X amount of money available for buffer stripping and X amount of money available for tree planting and X amount of money available for weir removal”. And there’s always then a scramble to get projects on that meet the criteria for each one of those

particular fields...This [PAR] I think is a very useful tool to actually get people round the table, sit down, look at the catchment, decide what the issues are in there, and then prioritise your action plan to address the pressures. And I think it corrects that sort of, at the moment things are sort of top down, driven from the top” (LRT member)

It would be unwise to conclude with a general truism that public participation always makes for better science, but the example of our project (and a wide interdisciplinary literature) shows that PAR can enrich scientific enquiry in certain contexts, especially where local knowledge may produce innovation in the questions asked, the processes followed, the research outcomes and their impacts. Importantly, PAR not only has the potential to result in enriched and innovative science, but provides a more democratic and equitable way of doing so than conventional academic and policy-making structures. In turn, as we have shown with the unexpected development of our farm vulnerability model, PAR can contribute new questions and directions for scientific enquiry.

Like Lane et al. (2011), we suggest that if the scientific method is removed from its traditional hierarchy of expertise, and scientists work with others in collaboration, research may become more democratic and innovative, but by no means unscientific. However, the innovations we described in the paper that were driven by the non-academic partners on the project have led us to question the distinction between ‘Experts’/’experts’ (Lane et al., 2011) and the notion of ‘redistributing expertise’ (cf. Lane et al., 2011; Landstrom et al., 2011). This terminology still points to a persisting underlying assumption that the academic, scientist or policymaker is the active partner

who is able to liberate local knowledge, determine and label expertise. Instead, in PAR, what takes place is a 'circulation of expertise' which flows from and to all of those involved whatever their training and background, resulting in a more fluid, dynamic and equitable exchange.

Despite the potential benefits of radical participatory approaches to environmental science, a number of structural and institutional barriers to deep participatory processes exist. By and large, Universities do not train scientists to work in this way, and it can take a change of culture as well as methodological learning for individuals to be able to use the PAR approach effectively. Others have argued that the success of radical approaches to participation involving natural scientists requires a process of 'dissociation' from scientists' own institutions and fields and 'attachment' to the people and issues in particular localities (Landström et al., 2011, p. 1631). While we would have some sympathy for this reconfiguration of scientific attachments and priorities, we fully recognize the practical difficulties that such changes can sometimes impose on environmental scientists.

Although the broad research process that framed this study can be used elsewhere (see Pain et al., 2012), PAR is not a one-size-fits-all approach; it provides framings and techniques to establish issues and questions, develop methods, conduct joint analysis and produce outputs together, but the details of process must be contextually specific. Consequently, genuine co-production of this nature tends to currently exist only at small and local scales (Landström et al., 2011; Maynard 2013); the scale at which policy-making is currently structured, even while policy bodies call for greater public participation, is a barrier to wider take-up. Tackling these barriers is important if the

co-production of issues and solutions outlined through PAR is to scale up and be able to inform scientific practice more widely. In addition, funding structures are not generally sympathetic to iterative research processes where specific questions are chosen and methods are fine-tuned during the research process, and where findings can be unexpected. Consequently, there remains a significant knowledge gap amongst funders and reviewers about collaborative and participatory forms of research, their traditions, practices and requirements.

Furthermore, participatory research may require longer timeframes, as dialogue and trusting relationships must be developed before project design can commence. While natural science research funders such as NERC in the UK now value participation, the grant application and peer reviewing process do not always sit well with this level of collaboration. However, the landscape is changing, and with research funders and institutions increasingly focusing on impact, it is hoped that natural science funding bodies will begin to recognize fuller processes of knowledge co-production in the way that social science funders (at least in the UK) are beginning to. The same critique applies to the policy arena, where water managers are being urged to facilitate public participation, but beyond the grassroots, efforts tend to be shallow owing to the difficulties of scaling up deeper engagement (Maynard 2013). At the same time as demanding participation, environmental planning is framed by government bodies in ways that constrain the power of smaller organisations and communities to prioritise and act on their own issues, and to engage more symmetric models of participation that challenge knowledge hierarchies (Cook et al., 2013).

Nonetheless, outside environmental science, PAR has been effective at multiple scales from the micro-practices of small groups and communities to macro-level political processes (Reason and Bradbury, 2008; Stringer, 2009). In this paper we have shown how it may also be successfully applied to an environmental issue. As PAR becomes more widely used in environmental science, the key challenge is how to keep its 'original visions and partnership ethics' intact (Reason and Bradbury, 2008, p.2) without it succumbing to the inherent limitations of more conventional forms of participation.

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