Integrating local knowledge with experimental research: case studies on managing cropping systems in Italy and Australia

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Abstract

The sustainable development of agricultural systems is currently challenged by many complex agro-environmental issues. These are characterized by an incomplete understanding of the situation and the problems that arise, and the conflicting opinions that result, issues over boundaries that are often difficult to define, and controversy over the multiple goals and uncertain outcomes. Added to these characteristics, we also have the slow and often inadequate uptake and implementation of research outcomes in this complex, *real* world. In order to improve sustainability of agro-ecosystems, agronomic research must move away from the linear research approaches and extension practices adopted so far that have focused purely on biophysical agro-ecosystems. The theoretical operational space of agronomic research must be transformed by considering agronomic issues as part of a broader social-agro-ecosystem. One aspect of this transformation is the inclusion of knowledge collected on a local level with the participation of farmers on the ground. The integration of local experiential knowledge with traditional agronomic research is by necessity based on the participation of many different stakeholders and there can be no single blueprint for how best to develop and use the input received. However, agronomists and policy advisors require general guidelines drawn up from actual experience in order to accelerate positive agronomic change. We address this need through a comparative analysis of two case studies; one involves multi-stakeholder research in a cropping system in the dairy district of Arborea, Sardinia, Italy. The central question was: *How can high crop production be maintained while also achieving the EU target water quality and minimizing the production costs?* The second case is a multi-stakeholder *soil health* project from south-eastern Australia. Here the central question was: *How can soil decline be prevented and reversed in this district, and soils made more resilient to future challenges?* The Social Learning for the Integrated Management and sustainable use of water (SLIM) framework, a useful heuristic tool for exploring the dynamics of transformational change, guided the analysis of the case studies. Within this framework, a key indicator of *success* is the emergence of new knowledge from the creation of new spaces for learning between researchers and local stakeholders. The Italian case study appears to have been the most successful in this sense, as opportunities for joint exploration of research data allowed new potential farming responses to the central question to emerge. The multi-stakeholder processes in the Australian case focused more on providing public openings for individual learning, and missed the opportunity for new knowledge to emerge through joint exploration. We conclude that participatory approaches may enable transformative practice through knowledge integration, but that this process is not an automatic outcome of increased community participation.

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Introduction

The sustainable development of agricultural systems is currently challenged by many complex agro-environmental issues. On a global scale, safe operating limits for climate change, biodiversity and nitrogen cycling already appear to have been exceeded, and there is immense anthropogenic pressure on land and fresh water, as well as on the global phosphorus cycle (Rockström *et al.*, 2009). The complex social-agro-environmental issues that arise in this context may be described as *wicked* (Ludwig, 2001) as they are characterized by an incomplete understanding of the situation and the conflicting opinions that result, issues over boundaries that are often difficult to define, and controversy over multiple goals and uncertain outcomes. Compounding these characteristics, and a cause of frustration to agronomists and other scientists, is the slow and often inadequate uptake and implementation of research outcomes in this complex, *real* world (Failing *et al.*, 2007; McNie, 2007). If, as we believe, the purpose of agronomic research is to contribute to the improved sustainability of agro-ecosystems, agronomy needs to move away from the linear research approaches and extension practices adopted so far that have focused purely on biophysical agro-ecosystems. Human values strongly influence the way in which knowledge is created and understood, and how decisions are made and action is taken (Durant and Legge, 2006; Folke *et al.*, 2010), so agronomic issues must be considered as part of a broader social-agro-ecosystem. In short, the theoretical operational space, or paradigm (Allen *et al.*, 2011; Ison *et al.*, 2011) of agronomic research must be transformed. Agronomic knowledge stemming from sources such as theoretical models, scientific experiments or the experiences of researchers has to be interpreted and fitted into the local socio-agro-ecological context. Similarly, local knowledge and skills could and should be better integrated into traditional agronomic research. The operational space of transformation thus centres on types of knowledge and their integration.

Readers of this Journal are familiar with the type of knowledge generated through traditional agronomic research, and here it only remains for us to note that it is objective and replicable, and often appears as non-contextual, *i.e.* isolated from its physical location and cultural history. *Local* knowledge, as we use the term in this paper, refers to a dynamic understanding that is continually developed through shared, on-site experience (Millar and Curtis, 1999). It may be subjective and/or objective, but it is almost always embedded in a local context. Local knowledge has traditionally influenced urban and community development processes (Corburn, 2003) and agricultural systems in developing societies (Kloppenburg, 1991). However, so far, local knowledge has not been fully used in agro-ecological research (Vigiak *et al*., 2005). This under use of local knowledge is particularly apparent in developed societies (Millar and Curtis, 1999).

Approaches and methods for integrating local experiential knowledge with traditional agronomic research are by necessity based on the participation of many different stakeholders. Participatory activities have become a common approach for many forms of policy implementation; recent examples include participatory decision-making (Ballard *et al*., 2008) and participatory planning and action (Reed, 2008; Mulas *et al.,* 2012). Various forms of Participatory Action Research (PAR) are also of interest as their design privileges local and/or experiential knowledge (Greenwood and Levin, 2000). PAR is a type of research used to build trust and consolidate interrelationships, and to allow locally relevant and immediately applicable knowledge to be developed (Kemmis and McTaggart, 2000; Allan *et al.*, 2007).

There can be no single blueprint for how best to develop and use these forms of participatory approaches. However, agronomists and policy advisors require general guidelines to be drawn up from actual experience in order to accelerate positive agronomic change. Pretty and co-authors (2010) gave this need expression when they published their *top 100 questions of importance to the future of global agriculture*. Their 63rd question asks: *What are the best social learning and multi-stakeholder models... to bring together farmers, researchers, advisors, commercial enterprises, policy makers and other key actors to develop better technologies and institutions, for a more equitable, sustainable and innovative agriculture?* This paper offers an answer by presenting the lessons from two cases of multi-stakeholder social learning for improved agronomic practice.

Materials and methods

To answer the 63rd question of Pretty *et al*. (2010), we present two case studies and analysis. Case study research aims to highlight interactions, common behaviours and structures within sectors of society (Hamel *et al.*, 1993). Case studies thus provide the context-dependent knowledge that is necessary to promote detailed understanding and learning, and ultimately expert practice (Flyberrg, 2006). As case study research reflects context, the act of delimiting the research case, and the boundaries of various features within it, requires consideration and justification (Fiss, 2009). Our case studies are opportunistic, in that we are learning about integration from projects we were already involved in, although this was not the projects' primary aim. We also take a comparative approach; while at first glance the cases from two very different parts of the world may appear too divergent for useful comparison, their shared focus on using PAR to promote more sustainable agronomic practice actually provides many useful insights.

The case study is a research strategy (Yin, 1994), and the evidence used in case study research may be qualitative and/or quantitative. This evidence may be gained through a variety of data collection methods (Fiss, 2009). The data collection method used for this paper is based on participant observation, including involvement in reflective *spaces* such as interactive workshops and participatory field experiments, supported by formal research interviews. In each case, the observations were formally and informally recorded by the authors during their involvement with their respective projects.

In this paper, the analysis of and comparisons between the two cases used a framework elaborated within the Social Learning for the Integrated Management and sustainable use of water (SLIM) project (2004) funded by the European Commission (5th Framework Programme for research and technological development, 1998-2002). The SLIM framework proved to be effective in enhancing understanding of complex issues that are characteristic of natural resource management, enabling participants to gain insight into the kinds of interventions that may be appropriate, and framing the research practice towards co-learning and co-research with stakeholders (SLIM, 2004; Roggero *et al.,* 2006; Collins *et al.,* 2007; Toderi *et al.,* 2007). The SLIM framework was developed as a heuristic tool for exploring the dynamic

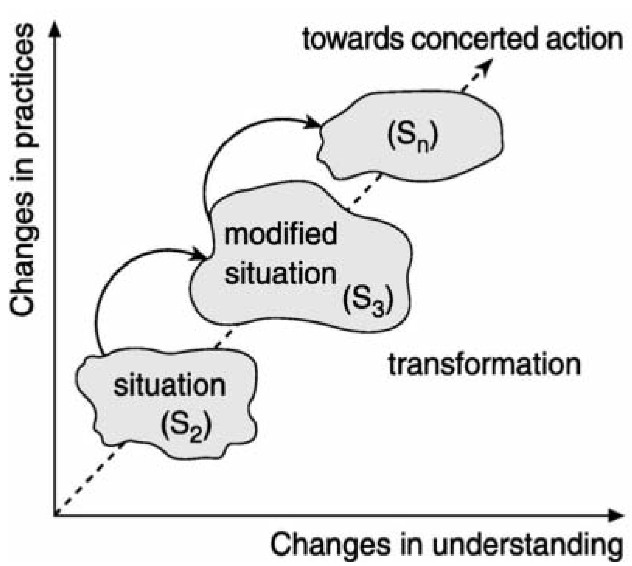

Figure 1. The Social Learning for the Integrated Management and sustainable use of water framework conceptualising transformation of practice through emergence of understanding.

of transformational change, understood as changes in practices with changes in understanding (Figure 1) in complex, uncertain, controversial and multi-stakeholder agro-environmental situations (Steyaert and Jiggins, 2007). In this context, interaction among stakeholders and the knowledge created through it can play a constructive role in changing relationships, understanding and, in turn, practices. Working within the SLIM framework has implications for research practice requiring that researchers play an active role in the creation of social spaces for interaction and learning. The SLIM rationale relied on the following logic: *Designated stakeholders engage in desirable practices, which require learning based on facilitation made possible by institutional support embedded in a Conducive Policy Context* (Ison *et al.,* 2007). Following this rationale, we compared the two case studies focusing specifically on the nature of the knowledge sought and found, and on the formal or informal learning spaces that facilitated the emergence of new reflective *spaces* for sharing knowledge among stakeholders. We propose the emergence of new knowledge from the creation of new spaces for learning between researchers and local stakeholders as the indicator of success of the process.

Case studies

Case study 1 includes socio-agronomic features of the intensive cropping system in the dairy district of Arborea, Sardinia, Italy. Until the 1920s, the site was a large, marine wetland. While there are remaining wetlands of significance, most of the land in Arborea was reclaimed and it is now one of the most intensive areas of dairy farming in Italy (170 dairy cattle farms and 35,000 cows in 5500 ha), with *per capita* milk productivity among the highest in Europe. Eighty per cent of the irrigated forage cropping system is based on a double rotation of silage corn and Italian ryegrass. In 2005, the European Union nitrate directive (ND) designated the Arborea area as the only nitrate vulnerable zone (NVZ) in Sardinia, as nitrates in the groundwater were higher than the legal threshold of 50 mg L^{-1}. This was considered to be due to the spreading of high rates of animal and human effluents derived from the intensive livestock farms (Sardinia Region, 2005).

Implementation of the ND has resulted in a series of obligations, including ensuring a maximum nitrogen (N) rate of 170 kg ha^{-1} $year^{-1}$ from organic fertilisers, forbidding the use of organic fertilisers between 15^{th} November and 15^{th} February, and respecting the Good Agricultural Practices Code. The prescribed maximum N rate is much lower than the N requirements of the major cropping systems in the area, which range from a minimum of 350 to a maximum of over 650 kg ha^{-1} $year^{-1}$, while the yearly production of animal effluents is much greater than the amount that may be applied. Consequently, farmers purchase and apply mineral nitrogen fertilisers to fulfil the total N crop requirement, while also paying to transport excess manure and slurry outside the NVZ area. The key agronomic question within this complex situation is: *How can high crop production be maintained while also achieving the EU target water quality and minimizing the production costs?*

Farmers from Arborea and the Italian research team have worked together on developing a common framework to address the nitrate issue. This shared operating framework became an important tool for learning in context (Eshuis and Stuiver, 2005). In this case, stakeholders actively focus and engage in a learning process in order to develop agronomic knowledge relevant to the specific situation of Arborea. This framework seeks to provide a substantial alternative to the largely *top-down*, agro-environmental management regime that existed before this project. This alternative approach could help generate the knowledge needed to formulate and revise the agro-environmental policy on a local level by including farmers' knowledge and views. Researchers involved farmers in designing a participatory process that spans field experiments and interactive workshops to address the questions that emerged (Toderi *et al.*, 2007). The process was designed to stimulate dialogue and interactive learning among farmers, researchers and other stakeholder categories to raise awareness of the nitrate issue, and create and agree on solutions towards a more sustainable management of the nitrogen cycle on the farm level. The field experiment was co-designed with a cattle farmer who volunteered to take part and was co-conducted on the farm to assess the impact of the ND obligations on crop productivity and on the nitrate concentration of surface and groundwater in an irrigated silage maize - Italian ryegrass double rotation. The experimental design (latin square with four replicates) compares four fertilisation methods (100% slurry, 100% manure, 100% mineral fertiliser, 170 kg ha^{-1} from slurry + mineral fertiliser at a rate sufficient to fulfil crop requirements and NZV limits) at a target N rate within this silage maize - Italian ryegrass double crop rotation.

The creation of opportunities for interaction and learning between the different participants was crucial to the aim of getting back to the basic problems, re-constructing the issues involved, and developing a common framework. Initially, two interactive workshops took place during the field experimental process to promote the exchange of information and knowledge around nitrate pollution issues and related policies. A final workshop was designed to allow participants to use their knowledge to interpret the research outcomes in order to enhance the understanding of factors that control the nitrogen cycle management and the impact of organic fertilisation on cropping systems and water, and help identify sustainable animal effluent management options. During these workshops, researchers played the role of informed facilitators rather than just providers of scientific knowledge. Participants were asked to interpret the results by themselves in the light of their own experience and expertise, and to propose feasible practical adjustments to the links between farming practices, crop productivity and water nitrate pollution using their own frames of reference to provide new opportunities for reflection among participants.

Case study 2 is located in the south-eastern Australian Holbrook district, an extensive agricultural area since European settlement in the 1830s. Principal activities are cereal cropping and cattle or sheep grazing. The ancient, colluvial soils in this district are generally acidic and less fertile than many European soils, although this is a productive area of Australia. Historically, cropping was rotated with a grazing phase; this allowed the soils to regain both structure and fertility from the clover-based pastures and animal manures. Recently, economic factors have encouraged more cropping, with fewer or no pastures in the cropping rotation, increased burning of crop residues, and more frequent aggressive cultivation. Combined with low rates of fertilisation, the agricultural productivity of many soils in the district appears to be declining. As in the Italian case, this situation is complex. Farmers are under pressure to intensify their agriculture in order to be competitive on global markets without increasing farm inputs. They are also being encouraged to prepare to respond to the as yet unknown impact from climate change, even though there is still disagreement over the best way to do this. The agronomic question in this case is thus broader than that for Case 1: *How can soil decline be prevented and reversed in this district, and soils made more resilient to future challenges?*

In this context, a project was created called *Meeting in the Middle* (MIM), a name that reflects its aim of integration. Operating between 2006 and 2008, the project aimed to bring together a number of perceived opposites, including conventional and biological farming approaches, farmers and researchers, practical and technical knowledge, as well as local and non-local sources of information (Allan and Wilson, 2009). The MIM project emerged through various informal conversations about soil decline between the individual farmers and staff from the government affiliated Murray Catchment Management Authority (MCMA). These conversations supported more formal calls from Landholder Advisory Groups for a comprehensive approach to soil health testing, monitoring, management and research in the MCMA area. Staff from the MCMA developed the MIM soil health project in consultation with a number of farmers, Government agricultural agencies and the two Australian authors of this paper (one a soil specialist, the other a social scientist). MIM aimed to use PAR to improve local understanding of soil health and how to maintain it. The project was funded by the Australian Government. After a well attended public meeting, a project committee was formed made up of volunteers from the Holbrook district farming community, and research and extension agencies. The committee was chaired by a farmer, and supported by the MCMA and the Australian authors of this paper. The committee met regularly to review and plan events. In brief, it planned and delivered soil health-based activities including six public seminars from soil experts (traditional and *alternative*) from outside the district, and a DVD recording of each was event made freely available. Other events were an interactive soil microbiology workshop and two literature reviews: one on soils and soil health, the other on participatory processes. The project also supported a university graduate research project on local indicators of soil heath (Kelly *et al*., 2009), and the establishment and initial inspection of two on-farm soil health demonstration/trials devised and implemented by the farmers with support from technical advisers.

Results

The results from these projects can be considered in a number of ways. Here, in keeping with the SLIM framework, we present results related to emerging agronomic knowledge, the nature of the opportunities created for that new knowledge to be evaluated and the understandings that emerged, and what the future of each process is likely to be.

Emerging agronomic knowledge

In Case 1, collaborative experiments yielded new knowledge about the nitrates dynamics in Arborea soils and surface water. Before the participatory field experimental process, farmers were not aware of the impact of their activities on water quality; they were defensive and considered their role to be relatively marginal. The fact that they did not consider nitrate pollution a serious problem reflects the difficulty of perceiving nitrates in water without appropriate instrumental means (Toderi *et al*., 2007). Some research and monitoring of nitrate pollution had been carried out by the research institutions and the regional environmental protection agencies. However, the connection between individual farm action and pollution had still been unclear. What farmers knew, from practical experience, was that the sandy soils of the district made the use of organic fertilisers essential if soil fertility was to be maintained. At an initial stage of the participatory process, farmers wanted to address the nitrate issue through the adoption of new technologies such as fertigation, separation of the solid fraction of the effluents, the construction of biogas plants, etc. On the other hand, researchers were more oriented towards changes in the cropping system that could lead to significant improvements in efficient N use in the field. The participatory field experiment enabled farmers to put information about nitrates in water into a context that was relevant to them. From the designing stage to the interactive workshops, the farmers were equipped with scientific knowledge that helped them interpret the pollution causes and in so doing acknowledge the role of farming practices. The co-design and co-conduction of the field experiment and interactive workshops with farmers provided opportunities to reflect together on the effects of livestock effluent management on crop productivity and nitrate pollution, and to identify possible farming practices to comply with the ND obligations and ensure farm income. Moreover, the collective evaluation highlighted that the vulnerability to nitrate pollution of groundwater was mainly associated to the high rate of organic effluent used as crop fertiliser in an area with a shallow water table and sandy soils. Several suitable farming practices in terms of responding to ND, maintaining economic profitability, and ensuring a sustainable livelihood were identified. For example, the practice of spreading one-third of the total annual slurry in the autumn for the ryegrass crop in the double crop rotation with silage corn was found to be a key weakness in terms of efficient N use. One of the options that emerged during the interactive workshops was that of reserving the entire annual rate of organic fertilisers for silage corn, using the mineral fertilisers only for ryegrass in late winter, to reduce the risk of nitrate leaching in the wet months. The implications of such an option on the storing capacity of the animal effluents were also explored, also in relation to the investment needed and the disposal of the excess effluents outside the NVZ. Furthermore, additional research issues to be addressed for sustainable cropping systems were also identified, such as the need for more sustainable irrigation management and P fertilisation schemes.

The approach to existing information in Case 2 differed to that in Case 1, as the project committee deliberately sought to review and reuse existing information on soil health and take it to a wider audience within the farming district. As one committee member noted: *... if we can locate a lot of research papers and information and so on, that may have been done through the years that's been shelved or dust has gathered or people haven't had the confidence or ability to find it or search it out... because I think it's not so much discovering new things it's discovering what's already there.*

The difference between this approach to information and emergent knowledge, compared with traditional agronomic extension practice, is that the local, farmer-based steering committee provided the main indication of what information was needed, and in particular which experts should be invited to speak to the wider community. This departure from the more traditional model of agency staff selecting the expert knowledge to be made available resulted in a wide range of speakers, including farmer practitioners and others with interests in biological, biodynamic farming and other non-mainstream cropping approaches, as well as more traditional soil researchers. However, this approach left little opportunity for new knowledge to be developed collectively.

Opportunities for reflection

In Case 1, during the interactive workshops, the agronomic researchers encouraged shared reflection on the agronomic knowledge generated through the on-farm, fully constituted field experiment. The researchers presented the results of the field experiment to the farmers and other stakeholders, and promoted discussion among participants to stimulate a collective interpretation of results. Researchers did not describe the research results as fixed or objective outcomes. Rather they asked participants to interpret the results for themselves and to propose possible links between farming practices, crop productivity and water nitrate pollution according to their own conclusions. Questions used to assist the participants included: *How do you explain/ interpret these results? Based on these results, which options do you think could address the problem and how would you plan to achieve them?* The main feature of this facilitating process is that the researchers promoted the position of farmers as both direct *users* of the scientific experimental results and also as providers of local knowledge and viewpoints. The new agronomic knowledge generated through these interactive workshops was the shared interpretation of farmers and researchers. Farmers interpreted the experimental results according to their practical experience and underlying knowledge, while the researchers' interpretations came from their experimental observations and their own underlying scientific knowledge. Promoting these processes also helped transform farmers from passive to pro-active participants and to take a key role in the management of the nitrate issue. The limits of these collective, reflective processes are that most of the participants in the interactive spaces created were farmers. Other stakeholder categories were less represented, although researchers believe that they could contribute relevant viewpoints and knowledge to the discussions. This is partially related to the different levels to which the stakeholders were willing to participate according to the extent to which they are involved and/or to the fact they do not always think they have a relevant role to play in addressing the issue at stake. Therefore, it is important to acknowledge the need to promote the emergence of new areas of involvement through wider formal interaction spaces, and, in this way, to enhance stake-holding in the broader sense of the SLIM project (Steyaert and Jiggins, 2007).

Activities initially promoted in Case 2 were designed to create a new way of approaching knowledge sharing. The first public meeting employed a professional facilitator to encourage the participants to co-design MIM by asking: *What are the soil health topics you would like to explore further/learn more about?* This public brainstorming session identified 19 topic categories, and these were discussed in smaller interest groups later in the workshop (Figure 2). The project committee formed at this meeting used a list of these categories to guide their subsequent discussions. The committee meeting that followed involved not only farmers' representatives, but also researchers and staff of the MCMA. Indeed, by this time, the MCMA had clearly taken on the role of manager of the project, and meetings, correspondence and project literature displayed the logo of the MCMA. This was interesting from two perspectives: i) it highlighted the need for agency to be *seen to be doing* in the region; and ii) it also highlighted the difficulty the agency had in relinquishing control of the project. Both of these aspects influenced the development of MIM. The other influential element appeared to be the involvement of a soil specialist. Despite the soil specialist's efforts to remain passive in the committee discussions and not influence the development of the project, the simple presence of such a specialist influenced the responses of some of the farmers, with some expressing a clear desire for the specialist to provide answers and become much more involved. Without a clear framework for shared discussions and knowledge integration, stakeholders fell into familiar patterns of behaviours and role-play.

It was apparent during the early committee meetings that the soil specialist and staff of the MCMA were having a dominant influence on the development of the project, shaping the boundaries within which the farmers in the committee and wider district could participate. Thus, the next stage of the project was the development of a series of information-sharing seminars, workshops and field trials; this was a much more traditional model of learning than had been intended at the start of the project. From then on, MIM put less emphasis on opportunities for reflection. Information was provided by a variety of people, but mostly in a traditional information delivery process, with public events offering little opportunity for analysis and reflection. One of the central tenets of MIM was to create public spaces for experts from within and outside the area. Speakers at the events often included local farmers who were encouraged to share their knowledge and skills with the wider audience. The two local trials were established with input from the hosting farmers and local members of the Steering Committee. As the project matured, some members of the Committee felt that local, practical knowledge and skills should be shared more, and the trials and final field day show a move in that direction. However, even at the local field trial day, the main invited speaker was a popular academic from outside the district.

Despite the move to a more traditional extension approach, the initial aims of the project remained, and discussion and analysis of the information that was being made available was encouraged at the project meetings. These attempts at analysis and reflection did cause some frustration, as expressed by a committee member: *You may get disappointed sometimes when the meetings just go around in circles and they talk a lot and they don't come up with anything but we have to keep going ahead and setting some hard goals and then get into it and do it.*

Eventually, committee discussions focused less on shared and new understandings of soil health knowledge and more on what types of expert knowledge needed to be sought and disseminated in the district, *e.g.* interpreting soil analyses for when to apply fertiliser or lime, or how to increase soil carbon through modified tillage. Alternative expert opinion was also sought on organic farming and increasing soil biota through crop selection and application of soil ameliorants such as biochar. These biological, alternative approaches to soil management were presented through demonstration/trial on the farms. One of the most well attended information events was the day dedicated to soil microbiology. This event was designed by the committee to encourage farmers to look at samples of their own soil through microscopes to learn about its biological component. Hence, expert and some local information was shared in a structured fashion with the wider community, but in separate packages accessed by individual farmers.

Emerging understanding

Each of the two cases presented different types of opportunities for analysis and reflection in which to create a wider understanding that could lead to agreement on the action to be taken for sustainable agronomic practice. In Case 1, the process of *learning in context* was undertaken in the Arborea context of a well-known nitrate pollution issue on which farmers and researchers have been actively involved in learning processes aimed at co-producing knowledge specific to their own experience. The *learning in context* process fostered the emergence of new, shared viewpoints on the nitrate issue and potentially more desirable agricultural management options to address it. Once the relationship

Soil
Balancing soil health and production
Indicators of a healthy soil
Soil testing
Organic matter, role of organic matter, soil carbon
Soil biology
Plant impacts on soil allelopathy, etc.
Water: how do we potentially increase water availability?

Farming approaches
What is the essence of biological farming?
Different management approaches
Conservation farming programme on the Tablelands
Alternative products and inputs

Communication and information
How to identify a priority (explore what is wanted)
Literature review to determine what we know and what we do not know
Look for gaps in knowledge
Information/legacy database to ensure that information is not lost

Figure 2. Categories of soil-related information needs identified in local Holbrook, Australia, farming community.

between farming practice and nitrate pollution in this location was better understood, the ND limits and obligations were considered to be insufficient to ensure the expected reduction in the risk of nitrate leaching and of water nitrate pollution compared to less costly fertilisation options. Participants, including the researchers, transformed their initial understanding of nitrate pollution in Arborea to enable them to create new and more numerous responses to it. Together study participants developed a series of responses and options. Farmers have identified several practical farming options considered as short-term strategies to comply with the ND requirements, while researchers acknowledged that farmers interpreted the experimental outcomes as a fundamental requisite to develop adequate scientific documentation for the request of derogation about the effluent application, given the huge impact of the ND implementation on milk production costs. Both farmers and researchers agreed upon the fact that several issues needed to be addressed in further research investigations and policy decision-making processes aimed at sustainable agricultural development in this specific context.

Case 2 provides less evidence of emerging shared understanding. A lot of information about agronomic practice and soil health was made available in the district via well-organized and publicized local events. Some of this information was used to design the two on-farm demonstration sites that were established. These may have provided the opportunity for new and shared understandings on potential agronomic responses to emerge, but by the time they were established, no further funding for activities was available. The conflicting understandings of both the causes of soil decline, and appropriate ways to tackle it, appeared to remain much as they had at the start of the project. There was evidence that individuals, particularly project committee members, had developed a more complex and refined understanding of soil health issues, reflecting the fact that, in this case, learning and change was an individual, rather than community, outcome.

Future prospectives

In Case 1, a process for continued co-learning was developed through the on-going research activities in the area and formal/informal interactions between the research team and farmers for the development of new research projects based on the trust and relationship that had been built up and the shift in attitude of the farmers during the study. These continued co-learning processes aim to improve the nitrate pollution and rural development in the area. The series of responses will be tested, and an analysis will lead to further questions and possible responses. Further questions were also raised by the participants in Case 2, but the ability to address these in a structured and participatory way was limited by the need to find new sources of funding, which were not available in the short term. The MCMA continues to deliver soil health information, but not in the MIM format. Individuals continue to work with soil health issues but there is no dedicated community forum in which to share ideas in a structured way. These various results are summarized for easy comparison in Table 1.

Discussion

In responding to Pretty *et al.*'s question, we have presented two examples of attempts at participatory learning. We have also suggested that the main indicator of success will be the emergence of new knowledge from the creation of new opportunities for learning between researchers and local stakeholders. The Italian case study appears to have been more successful in this sense, and we will reflect on the factors that enabled or constrained emergence of new knowledge to provide guidance for agronomists seeking to use participatory methods in their own research programs.

Both projects sought to situate experimental agronomy and diverse knowledge into a local operational context with high-level drivers for change. Both projects began by recognizing that they were seeking new processes for continued development of emerging understanding and collective agreed actions, rather than a particular *state* or single answer. To achieve this, both turned to a form of PAR. However, while Case 1 focused on collaborative and local experimentation, Case 2 drew on information that was already available, with the field demonstrations occurring after, and partly in response to, the presentation of this information. Another key difference in the cases was the nature of the opportunity for analysis and reflection that was created around the project activities. Case 1 used workshops to encourage shared analysis and reflection on the new agronomic knowledge from the trials. Case 2 began this way, but, as described above, returned to using a mostly traditional extension approach that anticipated individual reflection and action, rather than a shared response. Shared reflection on the two

Table 1. Summary of results.

Cases	Emerging agronomic knowledge	Reflective space	Emerging understandings	Future
1. Italy	Collaborative experiments yielded new knowledge about N dynamics in Arborean soils	Workshops encouraged shared reflection on the new agronomic knowledge	A series of responses and options was developed in a collaborative setting	A process for continued co-learning was developed. The series of responses will be tested, and analysis and reflection will lead to further questions and possible responses
2. Australia	Collaborative experiments yielded new knowledge of influences on some soil parameters	No opportunity for shared reflection. Instead, expert knowledge was sought and shared	Conflicting understandings of the issue and possible responses remain unexplored	Individual farm experiments with informal sharing of results with other farmers, mostly without expert agronomic advice

N, nitrogen.

Table 2. Differences between the case studies.

Cases	Emerging agronomic knowledge	Reflective space	Emerging understandings	Future
1. Italy	Collaborative experiments yielded new knowledge about N dynamics in Arborean soils	Workshops encouraged shared reflection on the new agronomic knowledge	A series of responses and options was developed in a collaborative setting	A process for continued co-learning was developed. The series of responses will be tested, and analysis and reflection will lead to further questions and possible responses
2. Australia	Gathered and presented a wide range of existing agronomic and other soil information before developing collaborative on-farm demonstrations	Little opportunity for shared reflection. Instead, a range of soil-related information was sought and shared	Conflicting understandings of the issue and possible responses remain unexplored	Individual farm demonstrations with informal sharing of results with other farmers, mostly without expert agronomic advice

N, nitrogen.

farm demonstration sites would have been encouraged, but the project finished before that could occur. Creating demonstration sites rather than experiments also limits the potential for new technical understanding to trigger emerging, unanticipated, adaptive responses. In Case 1, a series of responses and options for an immediate and pressing problem was developed in a collaborative effort. This contrasts with Case 2 in which conflicting understandings of the issue and possible responses were presented without attempting to produce a shared response. Finally, Case 1 occurred over the medium term, and has the potential for new understandings and practices to continue to emerge and change over time. The short duration of Case 2 limited what could be attempted and what, finally, was achieved. The differences between the two cases are summarized for comparison in Table 2.

Our experience suggests that agronomic researchers designing participatory approaches to integrate local and other knowledge should do so only after careful consideration of a number of issues. The first relates to the nature of the *entry point* for the participatory process. The Australian *entry point* was declining soil health, a chronic, slowly evolving and poorly defined problem. The Australian farmers recognized that conventional solutions and delivery of information was not addressing their needs, and it was their concerns that prompted the creation of the project. Even so, there was little shared understanding of what the problem actually was, what caused it, or how urgently action needed to be taken. The nature of this issue is such that it is not easily defined, and responses to it will not only differ according to the different biophysical properties of the soils, but also because of differences in the farmers' understanding and experience. By contrast, the ND impacted on farmers' practice and profits in a way that was immediately recognizable by everyone involved, and with an urgency derived from the imperative to comply. The single definable issue of the ND was thus a type of *crisis* facing farmers, and crises allow rapid collaboration, building of trust and concerted action (Bormann and Stankey, 2009; Olsson and Folke, 2001). This is not to suggest that participatory approaches are only valuable for crisis entry points (or that a crisis should be created), but rather that the nature of the entry point should influence the overall design of the participatory approach. In hindsight, a longer, staged approach for Case 1, such as developing a shared understanding of the issue, then of participation processes, before even thinking about shared responses, may have encouraged the emergence of new potential management practices. A staged approach such as this would increase both the time needed to bring people together, and also the risk of *failure*, as participants may get tired of conversation without clear action. To manage that risk, the framework for discussion in the early stages would need to be carefully developed and monitored to enable discussion and reflection to be assessed as *progress* by those participating. Designing a participatory process around some form of *crisis* as an entry point also needs care, as there is the potential for the participatory process to remain focused on the single issue unless processes are developed to place the crisis in the broader socio-agro-ecosystem. The participatory agronomic field experiments in *crisis* situations become crucial as they build the basis for agricultural innovations of farmers, and are a means to enhance local knowledge (Leitgeb *et al*., 2008). In Case 1, farmers used the research results as information to help recognize the nitrate pollution and find better agronomic farming practices. Innovations of farmers in Case 1 also went beyond the single issue of nitrate pollution as farmers sought the assistance of researchers in developing project proposals to search for financial resources for agricultural development and environmental management (*e.g.* the rural development program funds of the Sardinian Region). Farmers' knowledge and views were used by the researchers as an additional source of information to help understand more fully the local agro-ecological issues and complement the scientific research results. The on-farm experiments in Case 2 were less integrated into their project. Not only was their establishment left until the end of the project, but they were also considered to be demonstrations rather than rigorous experiments that would create new knowledge. To enable agronomic experiments to be effective tools for building social-agro-ecological resilience, they should be designed and integrated into a learning process. This can potentially make use of the participatory process not only to address the emerging questions like the nitrate issue but also to foster farmers' innovations in rural and agricultural development within the local political and institutional domains.

Another issue for project designers to consider relates to knowledge and how this is integrated. These cases suggest that every participant, regardless of their background, can benefit from the creation and sharing of participatory knowledge. As demonstrated in Case 1, local knowledge can increase the effectiveness of agronomic research outcomes because the new knowledge and understanding created directly influences new practices. For instance, the practical feasibility of adopting new cropping systems (*e.g.* add a catch crop between silage corn and ryegrass to increase nitrogen uptake) is enhanced since site-specific constraints, such as water table dynamics or labour costs, that are well known to farmers but not necessarily to researchers are taken into account. Although in the end Case 2 created less opportunities for participation than anticipated, farmer involvement in the selection of experts and their fields of expertise provided a wider selection of soil health information than would otherwise have been available. Conventional farmers were exposed to knowledge on soil biota, some soil health advantages of more conventional approaches were shared, and, importantly, the more traditional experts were shown that biologically focused information could complement rather than contradict conventional agronomist advice. Because they contributed to the creation and/or sharing of the new knowledge, farmers can develop their own ways to incorporate it into new or modified practice. This immediate adaptation helps to ensure productivity in the short-term strategies while aiming for longer-term environmental gains.

Our comparative study suggests, however, that the benefits of knowledge integration do not necessarily occur just because multiple types of knowledge are shared in a public place. Case 2 underlines that the opportunities for information sharing and the creation of joint knowledge need to be developed and maintained if participants are to benefit. How the reflective process is created and maintained is central to the success of the approach. Success depends partly on balancing planning and flexibility, and knowing which stage of the process requires each. We suggest that careful planning is needed when considering the scope of the project, especially what can be attempted and what resources, including time, will be required. Planning is also needed to allow the knowledge integration process to develop from the entry point to a system. Too much detail in the planning, can, however, remove the flexibility that is needed to respond to emerging initiatives and outcomes. For example, targets set in the project design stage of Case 2 drove the need to host a set number of traditional seminars, reducing the capacity for the project to respond to the emerging needs for *proof* through in-field demonstrations. Reduced ability to respond to emerging needs reduced the trust among participants, and trust is hugely important in participatory process, as shown by Shindler and Cheek (1999). Agronomic research practice should acknowledge that trust is a key ingredient to trigger learning and, therefore, changes in practices, and, hence, efforts should be made toward trust building and maintenance.

Conclusions

This research study suggests that PAR could be one of the social learning and multi-stakeholder models that bring together farmers, researchers, advisors, commercial enterprises, policy makers and other key role-players to develop better technologies and institutions, for a more equitable, sustainable and innovative agriculture, at least in our context of sustainable management of cropping systems. It can achieve this through integrating knowledge to allow new, transformed practices to emerge. However, this is not an automatic outcome of increased participation.

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