Socio-Ecological Practice Research (2023) 5:159–174
https://doi.org/10.1007/s42532-023-00149-7

REVIEW ARTICLE

A typology to guide design and assessment of participatory farming research projects

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Received: 16 December 2021 / Revised: 28 February 2023 / Accepted: 2 March 2023 / Published online: 7 April 2023

Abstract

Participatory modes of agricultural research have gained significant attention over the last 40 years. While many scholars and practitioners agree that engaging farmers and other stakeholders is a valuable complement to traditional scientific research, there is significant diversity in the goals and approaches used by participatory projects. Building on previous conceptual frameworks on divergent approaches to participatory farming research (PFR), we propose an updated synthetic typology that can be used to design, evaluate, and distinguish PFR projects. Key elements of our typology include a recognition of the multidimensionality of projects that reflect different combinations of: (a) the goals or motivations behind engaging farmers in research, (b) the specific methods or approaches used to implement a PFR project, and (c) the social, institutional, and biophysical contexts that shape the dynamics and outcomes from PFR. We use this typology to highlight how particular manifestations of participatory agricultural research projects—ranging from farmer advisory boards, on-farm demonstrations, and researcher- versus farmer-led on-farm research projects—combine goals, methods, and contexts in distinctive ways. Proponents of PFR projects would benefit from clarifying how their work fits into or extends this multidimensional typology.

Keywords Participatory farming research · Ways of knowing · Decision-making authority

1 Introduction

Conventional scientific research has been credited with impressive gains in productivity and efficiency in the USA and global agriculture. However, the traditional transfer-of-technology (ToT) model in which scientific innovations are created by experts then disseminated to farmers has come under increasing criticism for generating undesirable environmental and socioeconomic externalities, and for ignoring the important role of farmer knowledge and peer-to-peer social networks in the evolution of complex farming systems (Neef et al. 2013). Researchers in the ToT model have often treated agricultural challenges as tame problems that are technical in nature and have mechanical, straightforward solutions (DeFries and Nagendra 2017). This approach fails to appreciate the critical role of cultural, social, and physical contexts play in shaping outcomes (Ashby 2003).

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Partly as a response to critiques of the ToT model, participatory approaches to agricultural research have attracted increasing attention since the early 1980s (e.g., Chambers 1983, 1994; Ashby 1986; Taylor 1991; Pretty 1995; Pound et al. 2003; Scoones and Thompson 2009). Advocates have argued that engaging farmers earlier in the research process can ensure new technologies are appropriate for target populations and that participatory methods are essential to develop and support more agroecologically based farming systems that rely heavily on locally managed biophysical and socioeconomic processes (Berthet et al 2016; MacMillan and Benton 2014; Sumane et al. 2018).

While many scholars and practitioners now agree that facilitating participation of farmers and other stakeholders can be a valuable complement to traditional scientific research, there is significant diversity in the specific motivations and approaches used, and in their epistemological assumptions about the value of knowledge generated from participatory research. In other words, all participatory farming research (PFR) is not equal. Examples of PFR in the literature include demonstration farms, use of farmer research advisory boards, implementation of collaborative on-farm research trials, and work by farmer-led research networks, among others. This diversity of approaches can create confusion and limits the potential to select the most appropriate approaches to engaging farmers in agricultural research.

Over the last 40 years, a number of PFR scholars and practitioners have proposed typologies and conceptual frameworks to help organize this diverse collection of activities. Lilja and Ashby (1999) differentiated projects based on the degree of decision-making control held by scientists vs. farmers and whether or not there was an organized effort to structure communication between researchers and farmers. Johnson et al. (2003; 2004) built on this work to propose a framework with three components: (a) a ladder of participation in which farmers are given more significant control over research decisions as you climb the ladder, (b) a recognition that farmer participation and control could occur at different stages of the research process, and (c) a recognition that participation could be used to achieve different goals or purposes (e.g., improving the efficiency and effectiveness of the innovation process vs. empowerment of rural people). Probst and Hageman (2003) proposed a similar framework that included these three attributes, but argued that attention should also be given to epistemological assumptions, the formality of research design and methods, the characteristics of participating farmers or stakeholders, and the role of external actors and broader policy or institutional context.

Most of these earlier approaches explicitly or implicitly suggested a broadly unidimensional framework in which combinations of goals/methods were arranged from low to high levels of farmer participation. In contrast, Neef and Neubert (2011) proposed a more fine-grained framework that integrated key concepts from previous work as well as additional classification dimensions based on their own experiences in participatory research and development projects (see also Neef and Neubert 2005). Their framework proposed six dimensions that could be used to account for the diversity of participatory agricultural research projects and their outcomes: *project type* (a combination of research objectives and institutional context), *project approach* (combining research methods, epistemology, plans and processes), *researcher characteristics* (previous experience, attitudes, and commitment), *stakeholder characteristics* (experiences, perceptions, and capacity), *interactions between researchers and stakeholders* (levels and intensity of participation and contributions by scientists vs. stakeholders, timing), and *stakeholders' benefits* (desired or intended outcomes, ranging from innovation, new knowledge, skill building, improved livelihoods, and empowerment).

While comprehensive, the Neef and Neubert framework blurs a critical distinction between internal factors involved in the design and implementation of a project, and features of the external social, institutional, and organizational conditions that shaped the ability of PFR projects to achieve their goals. Moreover, the framework they propose fails to capture some of the important concepts and distinctions that have been raised in earlier work. In this paper, we use a narrative review of the published literature on participatory methods (in both agricultural and non-agricultural contexts) to propose a relatively simple typology that captures the diversity of PFR methods that can be combined in different ways on different projects. We use this typology to classify a number of prominent PFR approaches in the literature to highlight some key differences across projects based on their goals and methodologies. We also suggest ways in which this typology can be used to guide the design, implementation, and critical evaluation of future on-farm participatory research projects.

2 Differences among approaches to participatory farmer research

Growing uncertainties due to climate change, increasing application of digital platforms by farmers, and appreciation for the complexity of farming systems has led to a resurgence of interest in on-farm research projects as a vehicle for transformational change in agriculture (Lacoste et al. 2021). In response, we conducted a comprehensive search of published articles indexed in the Web of Science through 2021 which include the following key terms: 'on-farm research,' 'on-farm experiment*,' 'farmer-led research,' 'participatory agricultural research,' and 'participatory on-farm research.' We focused our search on examples of PFR work, particularly papers that categorized or distinguished differences in goals, methods, and approaches across the literature. This review helped us identify some of the diverse motivations/goals, methodological approaches, and epistemological assumptions about the status of knowledge created by non-scientists across these projects. Additionally, this search uncovered a number of synthesis papers that offered theoretical concepts and proposed methodological frameworks to characterize and critique different manifestations of PFR. Below, we draw from this previous work, as well as from the larger literature on participatory approaches to research (from non-agricultural settings), to outline a multidimensional classification scheme or typology that can be used to recognize and understand the implications of different choices for how to organize, implement, and evaluate PFR.

2.1 Objectives/goals for PFR

One of the critical distinctions between alternative approaches to participatory research is reflected in the diverse goals or underlying motivations for involving farmers and other stakeholders in agricultural research. A number of authors have presented schema to categorize the different goals or objectives that they expect to come from using PFR. Most highlight a difference between *functional* and *normative* outcomes (Hellin et al. 2008; Neef and Neubert 2011).

Functionally, participatory approaches can be used to ensure that agricultural research done in a manner that increases the validity, usefulness, or efficiency of the research process and the adoption or utilization of new knowledge and technologies (Lilja and Bellon 2008). In the broader participatory research literature, Blackstock et al. (2007) differentiate between two subcategories of 'functional' goals: (a) *instrumental* motivations, that focus more on using collaborative approaches to defuse conflict and increase acceptance of scientific work, and (b) *substantive* motivations in which the inclusion of multiple perspectives can both improve our basic understanding of and help identify the most appropriate solutions for the context.

Normatively, participation may be used to achieve specific ethical or moral objectives. This often includes the goal of addressing social and economic inequality by bringing underrepresented voices into the research process and/or using participatory methods to give more power to disadvantaged groups and communities to advance their own interests (Hacker 2013; Wilson 2019).

2.1.1 Functional–instrumental goals

PFR methods are often motivated by functional–instrumental goals to increase trust and acceptance of scientific knowledge and ultimately to accelerate adoption of new agricultural innovations. In contrast to functional–substantive goals (discussed below), functional–instrumental goals generally do not expect farmers' knowledge or feedback to seriously alter the trajectory of scientific research and discovery. Instead, participation is focused on helping farmers understand how to apply, adopt, and eventually disseminate knowledge and innovations that were produced using traditional scientific methods.

Lawrence et al. (2007) noted that some farming systems researchers working on international development view farmer participation mainly as a mechanism to validate new technologies, tweak or establish 'proper' input levels, and identify the most attractive packages of practices that can be used in extension programs. In each case, the emphasis is focused on helping researchers demonstrate the relevance of their research so they can accelerate farmer implementation of scientifically recommended practices (Lacoste et al. 2021). Johnson et al. (2004) also point to projects where 'turnkey solutions' are presented, and farmer participation is designed to identify barriers that need to be overcome in order to increase uptake and use of scientific research and new innovations.

Functional–instrumental goals in PFR parallel work from sustainability science and sustainability transitions literature that focuses on the mechanisms of collective or social learning (Van Mierlo and Beers 2020) and the use of processes that engage societal actors more directly in the scientific process (Schneider et al. 2019; Turnheim et al. 2015). This work often seeks to engage societal actors (or non-scientists) less because they can contribute special and complementary forms of knowledge to a research process, and more because these are the actors whose understanding and decisions are critical to any societal transformation.

2.1.2 Functional–substantive goals

By contrast, researchers working on complex farming systems or in resource constrained settings have long recognized that farmer feedback can also be useful in directing the design and implementation of formal scientific experimental methods which can substantively shape the actual knowledge that is generated. They have argued that engaging farmers as partners allows research scientists to test their knowledge and findings under working farm conditions and to collect farmer input on the interpretation of scientific findings and evaluation of recommendations (Lambrou 2001; Hellin et al. 2008; Hurst et al. 2022). Engagement can also be used to create or adapt new technologies or management practices to ensure they are able to address the needs of diverse producers (Hermans et al. 2021). For example, scientists using participatory plant breeding methods can ask farmers to identify traits important to them so they can be prioritized in crop or livestock breeding programs (Sperling et al. 2001; Witcombe et al. 2005). In this way, farmer feedback can substantively impact the conduct and trajectory of scientific research.

In addition to shaping scientific agendas and adapting scientific recommendations to better fit local situations, substantive motivations for participatory research can also include a desire to incorporate farmer observations and experiences as intrinsically important and complementary sources of knowledge. To many practitioners, PFR should quintessentially be seen as a process of co-production of knowledge (Brugnach and Ingram 2012) that combines alternative ways of knowing (representational, relational, and reflective). Scientists may elect to collaborate with farmers to co-produce new knowledge by combining scientific experiments with insights and findings based on farmer observations and accumulated experiential knowledge (Lawrence et al. 2007).

The use of participatory approaches to capitalize on the lived experiences and accumulated knowledge of practitioners is a core element of what is often called 'post-normal' science. Unlike 'normal science,' in which problems are divided into smaller and smaller questions to be answered by expert scientists using reductionist methods, post-normal science (PNS) is explicitly designed to be used to address complex scientific questions in which 'facts are uncertain, values in dispute, stakes high, and decisions urgent'

(Funtowicz and Ravetz 1991, p.138). To advance under these conditions, it is argued that knowledge about risks and hazards can benefit from incorporating information from people with lived experience, so-called extended facts coming from an extended peer community (Turnpenny et al. 2011, p.292). Criteria for evaluating the validity of knowledge claims under PNS approaches also emerge from a process in which societal actors engage in dialogue with experts to jointly assess their merits (Funtowitcz and Ravetz 1993, p.744).

Aksoy and Oz (2020) have argued that participatory methods can help farmers and researcher find a common language that places two distinct forms of agricultural knowledge (traditional and scientific) on an equal ground. On-farm research and collaboration can be an important technique to discover or validate existing farmer knowledge and understandings of the impacts of agricultural management practices and technologies (Witcombe et al. 2005; Ceccarelli et al. 2003; Ceccarelli and Grando 2007). One approach is to support farmer research networks that facilitate peer-to-peer exchange of observations and experience to accelerate the accumulation of collective knowledge among farmers, as well as to make that information more available to scientists working on the same farming systems (Probst and Hagemann 2003).

The idea that understanding the dynamics of complex systems (and developing solutions that can actually effect changes in the world) requires scientists to engage with non-scientific actors is a core tenet of most transdisciplinary (TD) research methods. TD approaches are generally characterized as research that (a) integrates methods and perspectives from multiple scientific disciplines to create a more robust interdisciplinary scientific understanding and (b) incorporates actors from the 'life-world' into the research process (Hadorn et al. 2008). Differences between traditional disciplinary (and interdisciplinary) scientific work and TD research generally lie in the levels of involvement and relative roles of scientists and societal actors in the process of problem identification, problem structuring, learning and analysis, and implementation of recommendations (Elzinga 2008).

In the context of PFR, Lawrence et al. (2007) have noted that there is often a tension between the perceived relevance and rigor of research depending on how much participants rely on formal research designs and the extent to which information from unreplicated and relatively simple observational trials can be integrated with findings from controlled on experiments. Pragmatically, this tension can be seen in whether or not results from on-farm observations and trials are taken seriously by scientists or project leaders, or given equivalent epistemological status as results from formal on-station experiments. Similarly, it is worth asking whether data and findings from PFR projects are expected to be publishable in peer-reviewed journals or generalizable to other regions beyond the specific farms or communities where research takes place.

The TD literature provides some guidance on these points. Epistemologically, many TD scholars distinguish between 3 types of knowledge: systems knowledge, target knowledge, and transformational knowledge (Pohl and Hadorn 2008; Smetschka & Gaube 2020). Systems *knowledge* reflects an understanding of empirical processes and interactions in the life-world that generates better understanding of how current complex systems work. *Target knowledge* helps identify needs for changes in current systems and the features of desirable alternatives. *Transformational knowledge* is about how best to transition from the current system to the target system (e.g., knowledge about technical, social, legal, and other means of action). TD (or PFR) methods can be used to produce all three types of knowledge.

2.1.3 Normative-empowerment goals

In addition to functional goals, participatory approaches may be used because it is normatively the right thing to do (Pretty 1995). These motivations for PFR often parallel the goals and methods used in the community-based participatory research literature discussed above—democratizing the knowledge production process, addressing structural inequalities, and generating social change (Bell and Reed 2021; Reason and Bradbury 2001). A primary normative goal is to increase the human and social capital of participants and empower them to solve their own problems through experimentation, adaptation, and innovation (Hellin et al. 2008; Lilja and Dixon 2008). Frequently these goals include a focus on traditionally marginalized or underrepresented farmers, including women, members of racial or ethnic minorities, or small or limited resource farms who are often not served by conventional agricultural research and extension systems (Johnson et al. 2004; Neef and Neubert 2011).

Hellin et al. (2008) make a distinction between using PFR to empower individual farmers and using it to strengthen intermediate organizations that support equitable and sustainable agricultural development. In the former case, the emphasis is often on building farmers' capacity to create networks or to use scientific principles to improve the pace and efficiency of knowledge generation (Ashby et al. 2000; Braun et al. 2000). Increasing local people's capacity for self-directed innovation can create conditions for emancipation or transformation of social inequality in agricultural settings (Probst and Hagmann 2003).

In the latter case, building better relationships between farmers and upstream development organizations or agencies can boost collective social capital and make institutions more responsive to grass roots needs and priorities (Johnson et al. 2004). Lawrence et al. (2007) point to a third phase of farming systems research that studies the complex system of interest as a whole, rather than attempting to control all the parts individually. In this approach, the emphasis is on developing a social learning process where researchers and other actors in farming systems learn how to contextualize and apply their knowledge and new technologies. Echoing the goals of sustainability transitions scholars, this focus uses PFR to create new social structures and institutions that are adapted to the needs of concrete needs and challenges faced by diverse farmer communities.

2.1.4 Non-research or manipulative goals

While PFR is generally pursued to advance either functional and/or normative goals, some scholars have noted that participatory engagement can also be deployed as a strategy simply to demonstrate or extend knowledge that had been generated through conventional (non-participatory) research, or what Pretty (1995) refers to as 'passive participation.' In these cases, the goal is not actually to do research and generate new knowledge, or to adapt scientific knowledge to local contexts, but rather to convince farmers to embrace the findings or recommendations of normal (mode 1) agricultural research. In this way, nominally participative processes can be deployed simply to gain the agreement of farmers and other target audiences for projects that experts or government officials have already decided were needed (Cornwall 2008). By emphasizing acceptance and adoption of scientific knowledge and innovations, these projects place most weight on what farmers can learn from researchers, such as learning new varieties' names and characteristics, or how to use their farms to demonstrate the benefits of recommended agronomic practices to other farmers. In extreme cases, insincere or 'manipulative' participatory approaches can even be used to generate acquiescence for programs or policies that may not be in local actors' best interests (Jones et al. 2014).

2.2 Methods for Implementing PFR

Aside from recognizing the distinctive goals that participatory agricultural research may be designed to accomplish, PFR projects can also be classified based on their choice of methods or approaches along a number of dimensions. These can include issues of decision-making (degree of farmer authority), timing (stage of the research process where participation occurs), structured communication (style and formality of interactions), representation (who participates), and location (where research takes place). In much of the literature on participatory research, the distinctions between the goals (discussed above) and methods of participatory research (discussed below) can be blurred. In our proposed typology, we seek to draw attention to the different combinations of goals and methods that may be observed across PFR projects.

2.2.1 Decision-making authority

Nearly all participatory approaches involve the use of methods, tools, and strategies that are designed to enhance the control of practitioners and beneficiaries on decision-making processes that affect their resources, works, and livelihoods (Bell and Reed 2021). In the community development or collaborative natural resource management literature, this can involve the devolution of decision-making power to individuals or groups in society who are directly impacted by public policy decisions (Reed et al. 2018).

When participatory approaches are used to conduct agricultural research, most of the key questions about decision-making authority reflect the balance of input and impact on final decisions allocated to farmers (and perhaps other stakeholders) versus scientists and researchers (Farrington and Martin 1988; Lambrou 2001; Neef and Neubert 2011). For example, Sperling et al (2001) distinguished participatory plant breeding projects based on whether they were initiated and led by farmers (farmer-led) or by external actors, like government or university programs (formal-led). Depending on the organization of a PFR project, farmers can play different roles that range from providing scientists with (a) land, labor, or seeds, (b) information about their problems or needs, and/or (c) technical or social leadership to help govern, manage, or implement a project.

Building on the concept of a 'ladder of participation' originally developed by Arnstein (1969), and applied to agricultural research by Biggs (1989) and Lilja and Ashby (1999), Johnson et al. (2003) have proposed a useful synthesis typology of PFR that includes 5 core rungs or degrees of participation:

- *Conventional* projects where farmers are asked to help implement research by providing land or labor to research projects that are fully conceived and designed by scientists, but where farmers have little input into the research questions or choice of treatments or methods. This has also been called 'contractual' participation (Biggs 1989; Probst and Hageman 2003), 'nominal' participation (Neef and Neubert 2011), or 'passive' participation (Pimbert 2011; Pretty 1995).
- *Consultative* projects where scientists actively consult with farmers to learn their opinions and preferences, but retain the final decision-making authority themselves. This has also been referred to as 'functional' participation (Pretty 1995).
- *Collaborative* projects where decision-making authority about research is shared equally between scientists and

farmers, also referred to as ‘cooperation’ or ‘co-learning’ (Cook et al. 2017), or ‘co-production’ (Reed et al. 2018).
- *Collegial* projects where farmers consult with scientists to get their input, but farmers retain the final decision-making authority. Some have referred to these types of arrangements as ‘interactive’ participation (Pretty 1995)
- *Independent* projects where farmers work with only nominal input from researchers to design and implement their own agricultural research projects, either individually or in groups. Others have referred to these as ‘self-mobilization’ (Pretty 1995) or ‘collective action’ research (Cook et al. 2017).

2.2.2 Timing of participation

Related to the different levels of decision-making authority given to farmers, some scholars have identified differences across projects based on the timing of when farmer input on research decisions is encouraged or allowed. Farrington and Martin (1988) distinguished three key stages of a research project where farmer participation could potentially be important: problem identification, conduct of the research, and dissemination of the research. Similarly, Johnson et al. (2003) write about the three stages of an innovation process:

- The *Design Stage* when problems or opportunities for research are identified and prioritized, there is an initial diagnosis of the problem and framing of research questions, and decisions are made about which new ideas to test, what outcomes to monitor, and which farmers or fields will be involved.
- The *Testing Stage* when potential solutions are tested and evaluated, including implementing fieldwork, monitoring progress and outcomes, interpreting the data or findings, and making decisions about what solutions to recommend.
- The *Diffusion Stage* where steps taken to build awareness of recommended solutions among potential users through the use of demonstrations, educational events, and development of extension or outreach materials.

Different PFR projects may target any or all of these stages.

2.2.3 Organization and modes of communication

A number of scholars have pointed to the importance of different ways to organize or structure communication and flows of information between scientists and stakeholders in participatory projects. In their work on forms of public engagement more broadly, Rowe and Frewer (2005) distinguish between three possible modes of information exchange: communication, consultation, and participation. *Communication modes* are characterized by one-way flows of information from experts to stakeholders or society. *Consultation modes* are used to solicit input from specific social actors on topics that have both been selected by scientists. *Participation modes* require full two-way communication between experts/scientists and the public where information flows in both directions with joint formulation of goals and outcomes. Reed et al. (2018) note that all three can be seen in self-described ‘participatory’ projects, but the first two are usually top-down approaches, while two-way exchanges can either be controlled by scientists, stakeholders, or some combination of the two.

Almost 20 years ago, Ashby and Lilja (2004) adapted these ideas in their typology of participatory agricultural research by emphasizing both the *direction* of information flows and the *degree of organized communication* that occurs within a project. This last criterion adds an important element since it helps distinguish participatory projects in which communication is systematic, consistent, intentional, and organized from projects that approach communication and information exchange in a more ad hoc manner. Neef and Neubert (2011) express a similar idea by highlighting the type, frequency, and intensity of interactions as a key dimension of classifying approaches to stakeholder participation in agricultural research.

2.2.4 Who participates?

The question of who participates—as well as who is excluded and who exclude themselves—is a crucial one when categorizing PFR projects (Leventon et al. 2016). Two aspects of who participates in a research process can help classify different approaches (Ashby 1996). One is whether the participants are *representative* of local farming communities or a population of target end-users. The second is whether the participants are *knowledgeable* or bring the right mix of relevant expertise to the process.

In the first instance, the methods scientists use to recruit or invite farmers can impact the degree to which PFR produces knowledge or insights that will be relevant to the full range of producers found in an area (Probst and Hagmann 2003). Most agroecological settings are characterized by social and economic differences where a minority of farmers have disproportionate access to land, labor and capital resources, while female, ethnic and racial minority, and limited resource producers face greater obstacles to their ability to take advantage of new innovations (Som Castellano and Mook 2022).

Depending on the goals and objectives of a participatory project, whether or not participants are representative of these different subgroups can make an important difference (Taylor 1991, p.45,48). Used effectively, participatory research grounded in diversity analysis can draw out and build on the range of perceptions, interests, and status found in farming communities to support more equitable and sustainable outcomes. To be effective, researchers should identify the key dimensions of diversity or difference that merit inclusion and design the process to ensure that key stakeholders are represented and able to participate. At a minimum, PFR projects that are conscious and intentional about the recruitment of farmers are more likely to ensure representation of the types of farms that are the target beneficiaries of their efforts.

In the second instance, projects that embrace and seek to incorporate the experiential knowledge held by local farmers may find that not all producers are equally skilled at observing outcomes associated with alternative management practices or accumulating knowledge about the dynamics of local agroecosystems (Farrington and Martin 1988). Som Castellano and Mook (2022) indicate that the research topic and question development process and methods can significantly shape the types of relevant stakeholders to include.

In both cases, whether or not the mix of farmer participants is 'ideal' will hinge on the overall goals or objectives of the participatory process. There can also be tensions between these two ideas since a farmer's familiarity and comfort with scientists and formal research institutions, ability to find time to participate, and capacity to experiment with alternative management practices are not equally present in fully representative groups of farmers (Neef and Neubert 2011). Similarly, without conscious efforts to understand and manage power dynamics across diverse farmer subgroups, participatory processes can struggle to get authentic and complete participation from the full spectrum of actors (Reed et al. 2018).

2.2.5 Location of research

Several authors have noted that the physical location where knowledge production and sharing takes place can shape who participates and whether and how new information is created and exchanged (Barreteau et al. 2010; Bell and Reed 2021). The strength of *on-station research* lies in the ability of research scientists to implement complex experimental designs and closely observe the results of treatments or manipulations under controlled conditions. A centerpiece of the traditional ToT model, on-station research is often conducted first to develop basic knowledge that can then be offered or conveyed to farmers (Leeuwis 2004). For example, fundamental knowledge about the biophysical dynamics of managed farming systems is often viewed by researchers as a precursor to helping farmers figure out how best to manage their operations (Toffolini et al. 2017).

By contrast, *on-farm research* can be done for several reasons. First, on-farm research provides an opportunity to test findings from on-station research under more realistic or representative production conditions. It can help scientists better understand the complex dynamics and interactions among elements of working socioeconomic and agroecological systems, and how actual outcomes from new management approaches can be shaped by the biophysical, cultural, and socioeconomic attributes of specific farming landscapes and communities (Wojcik et al. 2019). If it is an explicit goal of the PFR project, on-farm research can also be used to gather and aggregate farmers' tacit knowledge and experiential observations about the performance of different management strategies. It can also provide a more intimate venue for deeper interactions and collaboration between farmers and scientists, where participants can deliberate and reflect on the connections and dissonances between experiential and expert scientific knowledge (Baars 2011).

2.3 Participatory farming research typology

These various dimensions which can distinguish between different approaches to PFR are summarized in Fig. 1. While we see strong potential linkages between the specific goals set out for a particular PFR project and the methods that would be most likely to achieve those goals, we also recognize that these may be combined in various and distinctive ways. In the next section, we review some of the most common examples of PFR in the published literature and classify them against this typology. Importantly, as with the framework proposed by Neef and Neubert (2011), our typology is multidimensional and not a simple 'ladder of participation' in which all dimensions move up and down a participatory spectrum in the same way.

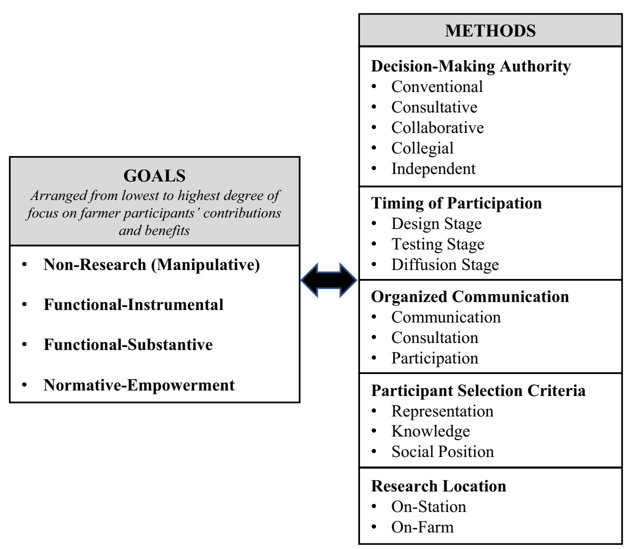

Fig. 1 Dimensions along which PFR projects can be classified

2.4 Recognizing differences across PFR approaches

There are a wide range of specific examples of PFR in the peer-reviewed publications that include some degree of farmer participation in agricultural research in the work identified in our search of the literature. While not an exhaustive list, below we highlight some of the more common exemplars below, using examples from published papers, and discuss how they can be categorized and distinguished by our PFR typology.

2.4.1 Farmer research advisory boards

Many traditional agricultural science programs at public land grant universities in the USA include the use of farmer and stakeholder advisory boards to review and provide input into ongoing research projects. This is particularly common for larger applied interdisciplinary projects, which comprise a growing share of the federally funded agricultural research portfolio. While there is virtually no published research literature on the various forms and impacts of these types of boards, in our experience they are usually expected to achieve both functional–instrumental and non-research goals. In the first instance, farmer input may be solicited about the broad topics that the research should address, and farmers may offer specific feedback related to particular methodological approaches or interpretations of the findings. In the latter case, advisory boards frequently serve a demonstration/outreach goal wherein results from research are shared with advisors to test how well they will resonate with the broader farming target audience.

Members of farmer advisory boards are rarely given much power to make decisions about core research design issues but more typically play a consultative role in which their suggestions and reactions may influence decisions by the scientists that implement the actual research. Advisory boards can weigh in at all three stages of the research process (design, testing, and diffusion). The structure and format of advisory board meetings comprise one exemplar for organized communication between farmers and scientists, and information flows reflect a consultation model in which presentations from scientists to researchers take up most time on meeting agendas, but there are designated moments where questions, comments, and suggestions are solicited from farmers.

In our experience, farmers selected to serve on advisory boards represent individuals who are identified as leaders in their industry, have the time and resources that allow them to attend advisory board meetings, and typically have denser social and professional ties to university researchers, government conservation agencies, and established farm or commodity organizations. There is evidence that women are underrepresented on advisory boards (Mackenzie 1994). They are much more likely to be selected for their expertise or social positions than to represent the full range or diversity of producer types.

2.4.2 On-farm demonstrations

On-farm demonstrations have long been a tool used by outreach and extension programs to bring greater visibility to new agricultural research or innovations (Ingram et al. 2018). Typically placed on working farms, on-farm demonstrations are designed to highlight the performance and outcomes associated with new seed varieties, technological innovations, or recommended management practices. While there are exceptions, in most cases the demonstrations are not designed to generate new knowledge or data, but rather are set up to bring attention to findings from more controlled experimental research that has already been done elsewhere. The main goal is thus not to do participatory *research* per se, but to partner with host farmers to use their farms to demonstrate to the broader farm community that new innovations or practices actually work under realistic farming conditions. Examples of situations where on-farm work is more oriented to answering fundamental or applied research questions are described in a separate section below.

Compared to other approaches to PFR, farmers that host on-farm demonstrations are usually given relatively little decision-making authority about the design of research (since it is usually already done), though they do get to decide if they want to participate, and which practices they want to highlight on their farms. In this way, they are participating at the last (diffusion) stage of the research and innovation process. On-farm demonstrations do represent a formal, organized form of communication between scientists and farmers, but the direction of information flows is typically one-way (educating farmers about scientific knowledge), with few organized mechanisms to incorporate host (or attendee) farmer feedback into future iterations of the research program.

In the literature, on-farm demonstrations are often pursued by researchers and extension specialists who recognize the importance of social networks and opinion leaders as key drivers of the adoption and diffusion of agricultural innovations (Rogers 2004). As such, selection of host farms frequently prioritizes individuals who are seen as influential and trusted sources of advice among their peers (Pappa et al. 2018).

2.4.3 On-farm research

In addition to advisory boards and demonstrations, the literature on participatory farming research includes many examples of actual research projects that take place under working farm conditions. These can be organized in many different ways, with varying goals, farmer roles, degree of organized communication, and methods for selecting participants.

Scientist-led on-farm trials: One subgenre of on-farm research involves trials that are designed by scientists, but implemented on a number of collaborating farms. There is a growing literature using aggregated on-farm data to answer scientific questions about the performance of different management practices under realistic management conditions (de Souza et al. 2012; Kharel et al. 2019; Kyveryga 2019; Laurent et al. 2019).

A primary goal of replicated on-farm trials is to test the performance or outcomes associated with different management practices under working farm conditions. Because of the logistical difficulties associated with incorporating complex research designs in the on-farm context, research designs tend to be simplified. For example, many on-farm trials involve split-field comparisons of two or three practices instead of replicated and randomized small plot designs. As a result of these limitations, on-farm research is used by scientists to advance a mix of functional–substantive and functional–instrumental goals. Substantively, there may be new knowledge generated that confronts or expands current scientific understanding of farming systems or the impacts of different management practices. More likely, however, the focus of the on-farm work will be on how best to adapt new innovations or practices to ensure they fit into the complex labor, management, and equipment constraints faced by actual farmers. In some cases, the on-farm research also serves an extension or outreach goal (similar to the discussion of on-farm demonstrations above).

Since they are normally designed and implemented by scientists, the host farmers may or may not be given much decision-making authority to refine research questions, contribute to research designs, or interpret the data coming from their farms. More commonly, their input is solicited at the testing (as opposed to design) stage of the research and innovation process. There is wide variation in the degree to which on-farm trials have organized mechanisms for structured communication between farmers and scientists. At one end of the spectrum, farmers may simply serve as hosts, but have few formal opportunities for engaging researchers in reviewing the findings. At the other end, farmers may be formally invited to help design the projects up front, provide input on or assist with field management and data collection decisions, and collaboratively engage with scientists in the review and discussion of the results.

Mother-baby trials: One variant of coordinated on-farm research is the Mother–Baby Trials (MBT) approach that has been used extensively in international development contexts (Snapp 2002). This approach typically pairs a replicated experimental 'mother' trial conducted under controlled conditions on a research experiment station with a set of simpler 'baby' trials that are implemented across a network of collaborating farms (Snapp et al. 2018). MBT projects typically blend research and empowerment goals. A major objective is to test alternatives under on-farm conditions and to incorporate farmer knowledge and preferences into research design and evaluation (functional–substantive). Some MBT projects also seek to empower farmers to innovate or adapt agricultural innovations to better fit their needs and ensure that development efforts benefit women and smallholder communities (functional–instrumental and empowerment goals).

Advocates for MBT approaches typically embrace an engaged and iterative learning model where farmers are given significant authority and control over the research design and implementation, and interactions between farmers and scientists take place through multiple iterative cycles of research where the trajectory of the research is refined and adjusted. Decision-making authority is typically shared (collaborative). Significant effort is devoted to organizing communication (e.g., through farmer trainings and meetings) that focus on two-way exchange of information (participatory modes).

Discovery Farms: In the early 2000s, extension personnel at the University of Wisconsin launched a collaborative on-farm research project to set up edge-of-field monitoring stations to quantify the impact of alternative management practices on water quality outcomes on a handful of Wisconsin farms (Frame 2000; Radatz et al. 2018; Stuntebeck et al. 2011). Research at these 'Discovery Farms' has been organized and coordinated by a farmer governing board, which leads the research design, interpretation, and recommendations associated with the work. At least one farmer-only meeting is held each year to review progress.

A major goal of the Wisconsin Discovery Farms (WDF) project is to improve understanding of how best management practices (BMPs) perform under realistic working farm conditions (functional–substantive goal), and to give farmers the ability to adapt or adjust recommended BMPs to better fit their farm operations (functional–instrumental). The WDF program also includes an extension/outreach component and there is also a strong assumption that giving farmers ownership and control over the research will lead to more rapid acceptance of the results and increase the rate of BMP adoption across the state (non-research goals). Farmers are typically engaged early in the design phase of the research and have the authority to overrule scientists when making research design decisions (a collegial mode). There is a well-established structure for organizing interactions between farmers and scientists, and information is exchanged using two-way communication modes.

In the ensuing years, a number of other states established their own Discovery Farm or edge-of-field monitoring networks, though the degree of farmer decision-making control and relative balance of research versus outreach goals seem to vary widely (Awole et al. 2018). For example, the Arkansas Discovery Farms (Sharpley et al. 2015) gather applied on-farm research data on a number of farms to compare conventional and recommended management practices using a similar paired field design. However, the project is less directly controlled by farmers and farmer participants (e.g., is more consultative than collegial). Similarly, the USDA Agricultural Research Service has installed surface and groundwater monitoring stations in 40 fields on 20 farms as part of an Ohio Edge-of-Field network (Williams et al. 2016). Farmers on that project negotiate with the scientists to determine which practices are tested on their farms, but most of the data collection, analysis, and interpretation activities are done by scientists then shared with the farmers. In both cases, the locus of decision-making is more consultative than collegial, and the level and direction of organized communication between farmers and scientists is less formal and more consultative than communicative.

Discovery farm programs generally target 'representative' types of farms. The WDF program sought willing and committed partners through a statewide call for cooperators, and selected farms if they represented 'typical operations and issues' faced by Wisconsin farmers (Frame, n.d.). The Arkansas DF program sough operations that are 'reflective of typical farming systems' (Sharpley et al. 2015, p.187).

Farmer research networks: One of the longest-running on-farm research networks in the US is coordinated by Practical Farmers of Iowa (PFI), a farmer-led organization established in 1987 (Thompson and Thompson 1990). PFI's goal is to 'empower farmers to generate and share knowledge through timely and relevant farmer-led research' (Practical Farmers of Iowa 2021, p.4). In 2020, 66 cooperator farmers participated in 81 research trials. Research topics and questions are generated by farmers, and research designs are crafted by farmers in consultation with PFI staff scientists. Projects typically involve at least 3 replications across each study field, and two or more treatment comparisons; frequently producers collaborate to reproduce similar trials across their farms. Farmers are responsible for implementing projects and taking measurements throughout the trials, and collectively share and review results and observations at an annual PFI cooperators meeting.

Another example is the Ohio State University eFields program (Ohio State University 2021). Led by a group of county extension educators and research scientists, the project matches individual producers with an OSU partner to design and implement relatively simple on-farm trials to compare multiple treatments using principles of randomization and replication. In many cases, research faculty identify a core topic and encourage local extension educators to recruit farmers to replicate the experiment on their farms. In other cases, topics and research questions emerge from discussions between farmers and county educators. Most eFields studies are run for one or two field seasons. Data are analyzed and reports produced by eFields staff. Results are shared in an annual summary report that is distributed in print and digital formats. A similar program has been run in Nebraska for over 20 years (Thompson et al. 2019).

A third model can be seen in the use of Farmer Field Schools (FFS) to engage groups of farmers in facilitated and coordinated research and learning programs, particularly around integrated pest management strategies. There is a large literature on the design and impact of FFS projects (Davis 2006; Feder et al. 2003; Van den Berg and Jiggins 2007). FFS projects provide training for farmers to conduct their own research, including research design, analytical skills, and problem solving (Davis et al. 2011). Groups of farmers are encouraged to observe and experiment on their farms to develop improved understanding of the functional relationships between pests and crops. Most FFS projects seek to address the needs of smaller and limited resource farmers in developing country contexts and embrace social values such as local agency, equity, and empowerment (Nelson et al. 2019).

These examples illustrate the broad range of goals and approaches used in on-farm research networks. Most value the intrinsic epistemological value of the information gleaned from on-farm research (functional–substantive), and nearly all embrace the value of on-farm research as a means to promote the practical use and adoption of new agricultural innovations (non-research). To different degrees, many farmer research networks also seek to empower farmers to take control over the research process and give them skills to answer questions without reliance on scientists. Farmer decision-making authority ranges from consultative to collaborative to collegial. Farmers usually participate in all three stages of the research process (design, testing and diffusion), but the depth of their role varies widely. There are different degrees of formal or organized communication and interactions between farmers and scientists.

2.5 Classifying different PFR approaches

Table 1 presents some of the key differences in goals and approaches that are associated with different types of PFR work. In some cases, it is possible to clearly and consistently identify the core or dominant goals or approaches associated with each type of PFR. In other cases, it would appear that there can be a wide variation in the ways in which the same PFR 'type' is implemented by project leaders.

Table 1 Common attributes of different methods of conducting PFR

	Farmer research advisory boards	On-farm demonstrations	Scientist-led on-farm research trials	Mother-baby trials	Discovery farms	Farmer research networks
Participation goal						
Non-research or manipulative	X	X			s	
Functional–instrumental	s		X	X	X	s
Functional–substantive			s	X	s	X
Normative-empowerment				s	s	X
Approaches						
Decision-making authority						
Conventional	s	s	s			
Consultative	s		X	s	s	
Collaborative			s	X	X	s
Collegial					s	X
Independent						s
Timing of participation						
Design stage	s		s	s	s	X
Testing stage	s		X	X	X	X
Diffusion stage	s	s	s	s	s	s
Organized communication						
Communication		s	s			
Consultation	s		X	X	s	
Participation			s	s	X	X
Participant selection						
Representation		s		s	X	s
Knowledge	s	X	s	X	s	X
Social position	X	X	X			
Research location						
On-station	X					
On-farm		X	X	X	X	X

X = most common approach; s = sometimes used

3 Discussion and conclusions

Calls to engage farmers in participatory agricultural research have been common since the 1970s, but the specific approaches used to implement this strategy have varied widely. This diversity of approaches presents a challenge to the systematic study of outcomes associated with engaging farmers in agricultural research. It also reflects some lingering conceptual confusion about which dimensions or choices are most important to consider when designing and implementing PFR projects.

Previous typologies of PFR (and participatory research more generally) have often relied unidimensional linear schema that array projects on a ladder or spectrum that range from low to high levels of participation. While the overall level of power and control given to farmers is indeed a defining feature, it can be helpful to recognize that PFR projects can vary along multiple and independent dimensions, and different combinations of traits are best captured in a multidimensional typology (e.g., Neef and Neubert 2011, p.182). In this paper, we have attempted to synthesize some of the existing frameworks into a comprehensive but still elegant typology. We encourage the application of our typology as a reflexive tool to guide the design or assessment of participatory agricultural research projects. By making choices about the goals, decision-making authority, timing, communication methods, and selection of participants on PFR projects more explicit, we will be able to learn more from past projects and improve the chances that future efforts can achieve their objectives (Barreteau et al. 2010, p.15).

In most instances, the combinations of methods used in PFR are linked either explicitly or implicitly to the particular goals or objectives of the organizers. For example, in the international development context, the limitations of conventional research and extension systems to address the needs of small and limited resource farmers were a primary motivation for exploring participatory approaches (Chambers 1997, p.5). This has led to a strong emphasis on methods that leverage farmers' tacit and experiential knowledge about local socio-ecological systems (systems knowledge) to improve the science (functional–substantive goals). They also reflect the use of PFR to build the capacity of local farmers to diagnose and address their own problems (empowerment goals). In turn, organizers are more likely to experiment with more radical approaches that give farmers more authority and control at earlier stages in the research process and devote significant resources to facilitating farmer-scientist and peer-to-peer exchange of information.

In the USA, PFR projects often have less transformative goals, with greater emphasis on engaging farmers in later stages of the research process to tweak or adjust the design of technologies (functional–instrumental goals) or that see on-farm research more as a mechanism to promote adoption of recommended management practices (non-research goals) and less as a site for serious knowledge production (Hurst et al. 2022). In such cases, we are likely to see more consultative modes occurring later in the research process with less of a focus on organized or facilitated two-way communication.

That said, the choice of any particular PFR approach depends on more than just the motivations of the organizers. As demonstrated by the Agricultural Innovation Systems literature (Hall et al. 2006; Hermans et al. 2021; Klerkx et al. 2012), the broader socioeconomic, cultural, and institutional context can affect the likelihood that particular outcomes will emerge. Some settings will be more conducive to successful participatory processes than others (Cornwall 2008; Reed et al. 2018). Institutional reward systems for scientists, farmer capacity to devote time to engaging in a participatory research project, and political acceptance of (or resistance to) the empowerment of farmers can all shape the conduct and outcomes of PFR (Barbercheck et al. 2012, p.96). In addition, awareness of the importance of context should not only shape the design or success of a project, but can also generate efforts to change reward systems, confront inequality, and redistribute power to ensure more effective and successful engagement of farmers in the co-production of knowledge (Ashby and Sperling 1995; Bell and Reed 2021, p.6; Whitton and Carmichael 2022).

The configuration of approaches may also be fluid over the life of a single project, and the motivations for participation may evolve for farmers and scientists over time (Reed et al. 2018). As such, expecting and designing flexibility into a PFR project could help ensure that the program can adapt to changes in goals, shared understanding, and socioeconomic and political contexts (Douthwaite and Hoffecker 2017, p.87).

To the extent that PFR is designed to generate useful knowledge of farming systems and to identify innovative management practices that can advance farmer and societal goals (Wiek et al. 2014), the epistemological status of farmer knowledge and alternative research designs is likely to be a source of tension. Scientists often question whether or not meaningful participatory on-farm research can be done without randomization and replication of treatments, and the use of experimental controls (Lilja and Bellon 2008, p.481). Some have worked to adapt formal scientific research designs to be more practical in an on-farm research context (Taylor 1991; PFI 2021). Others celebrate the more holistic and situated knowledge held by farmers, and question whether imposition of reductionistic research scientific methods is necessary (or even desirable) on participatory research projects for knowledge co-production, especially in research networks (Bidwell 2009, p.745; Hurst et al.2022). In any case, the enduring tension between rigor and relevance is likely to impact the evolution of PFR methodologies for years to come (Lawrence et al. 2007, p.163). Lessons from the large and expanding literatures on transdisciplinarity, post-normal science, and community-based participatory action research (CBPAR) provide a wealth of guidance on how best to negotiate these bumpy roads (Barreteau et al. 2010; Bell and Reed 2021; Funtowitcz and Ravetz 1993; (Maida 2009; Nowotny et al. 2001; Pohl and Hadron 2008; Smetschka & Gaube 2020; Stringer 2007; Turnpenny et al. 2011; Wallerstein and Duran 2010).

In this paper, we have drawn from a large and diverse literature on participatory farmer research to outline a practical typology to guide the design, implementation, and evaluation of PFR projects. Based on our work in both US and European contexts, we believe that there remains considerable variation in the ways that practitioners use the terms 'on-farm research' and 'participatory farmer research.' It is our expectation that this typology can help clarify differences across projects and ensure that the design of PFR methods is appropriate to achieve the specific goals of the project. Moreover, we hope that the typology will provoke some deeper reflection about the possible motivations and applications of PFR among scientists (and non-scientists) who have a general interest in the idea, but have not had the opportunity to read widely in this literature. This includes asking hard questions about what level of farmer involvement they are prepared to support, the level of control and power that farmers are given, the types of communication they use, and the ways in which they recruit different types of farmers to participate in PFR projects. We hope that these reflections will provide greater opportunities for deeper levels of engagement with farmers in on-farm research projects and create pathways to new forms of innovation and discovery that can help a broader range of farmers adapt to future climate, market, and political changes in ways that increase their social, economic, and environmental sustainability (Douthwaite and Hoffecker 2017).

Acknowledgements An earlier version of this paper was developed through an interdisciplinary workshop supported by the Agriculture and Food Research Initiative (AFRI) *Advancing Scholarship and Practice of Stakeholder Engagement in Working Landscapes* (Grant No. 2020-01551 Project Accession No. 1023309) from the USDA National Institute of Food and Agriculture. Contributions and input from workshop participants are reflected in this final product. Partial funding for the project was also supported by the U.S. National Science Foundation Innovations at the Nexus of Food, Energy, and Water Systems (INFEWS) Grant No. SES-1739909.

Author contributions All authors made substantial contributions to the conception, design, literature review, analysis, drafting and revising of the final manuscript.

Funding Partial funding for this paper was provided by a USDA AFRI grant and a National Science Foundation Grant (see acknowledgements above).

Data availability Not applicable.

Code availability Not applicable.

Declarations

Conflict of interest The authors have no competing, financial, or proprietary interests in any material discussed in this article.

Human and animal rights Human subjects were not involved in this research.

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