frontiers | Frontiers in Sustainable Food Systems

TYPE Original Research
PUBLISHED 24 July 2023
DOI 10.3389/fsufs.2023.1162658

OPEN ACCESS

EDITED BY
Philippe V. Baret,
Université Catholique de Louvain, Belgium

REVIEWED BY
Christopher M. Bacon,
Santa Clara University, United States
Ika Darnhofer,
University of Natural Resources and Life Sciences Vienna, Austria

*CORRESPONDENCE
Chris Maughan
✉ chris.maughan@coventry.ac.uk
Colin Ray Anderson
✉ Colin.Anderson@uvm.edu

RECEIVED 09 February 2023
ACCEPTED 27 June 2023
PUBLISHED 24 July 2023

CITATION
Maughan C and Anderson CR (2023) "A shared human endeavor": farmer participation and knowledge co-production in agroecological research. *Front. Sustain. Food Syst.* 7:1162658. doi: 10.3389/fsufs.2023.1162658

"A shared human endeavor": farmer participation and knowledge co-production in agroecological research

Chris Maughan[1]* and Colin Ray Anderson[2]*

[1]Centre for Agroecology, Water and Resilience, Coventry University, Coventry, United Kingdom, [2]UVM Institute for Agroecology, University of Vermont, Burlington, VT, United States

Farmer participation in the co-production of knowledge has been claimed to have many benefits, including its capacity to address the knowledge intensiveness and ecological specificity that underpins agroecology. The complexity of agroecological knowledge systems have until now presented considerable challenges to researchers looking to develop research practices adaptable to and commensurate with the integrative ambition of agroecology. As with agroecology in general, participation in research cannot be delivered in a one-size-fits-all approach, with each case needing to be designed on the basis of numerous factors, especially including the needs, objectives, and capacities of diverse participants. This article presents a conceptual framework to explore farmer participation in the co-construction of knowledge in agroecology. Through an exploration of three UK-based participatory research projects we develop a framework to better understand the practical challenges and opportunities for deepening the co-construction of knowledge. Using a combination of field notes, interviews, and survey data, the article concludes by offering practical reflections on ways to co-design research based on the type of knowledge(s) produced, the types of participation envisaged, as well as the needs and capacities of the research participants themselves. The framework presented in the article is offered as a tool to guide early stages of research design in order to balance the complex and changing needs of researchers and their collaborators.

KEYWORDS

agroecology, knowledge co-production, participatory research, farmer participation, plant bioindicators, appropriate technology, participatory field trials, ways of knowing

1. Introduction

The evidence is now incontrovertible that industrial farming is pushing us to the brink of our planetary limits (Campbell et al., 2017). From the depletion of natural resources to the degradation of life support systems and widening inequalities, agriculture as it is currently configured poses a major challenge today and for future generations. But what does it mean to walk it back, to undo the damage it has caused? Much like the industrial project in general, industrial farming was predicated on the outsourcing of "difficulty," whether by drawing on cheap pools of energy (i.e., fossil fuels), technology (i.e., repurposed weaponry), labor and land (i.e., via the ex-colonies), or by outsourcing knowledge itself (i.e., via elite research institutions and intellectual property). To reverse these processes will require the substantial reintegration of these elements back into our food systems and in ways that ensure their permanent regeneration and availability (IPES food and ETC Group, 2021).

As a paradigm, "agroecology" speaks directly to this need to restore and reintegrate —it starts from the perspective that food systems cannot be considered as separate from natural and human ecosystems: the healthy functioning of one depends directly on the other (Gliessman et al., 2022). The principles of agroecology have been built around this idea, not only prioritizing the recycling of resources and nutrients, but that food systems also become more just, by co-creating knowledge, ensuring democratic participation in food system governance, and by honoring and restoring our collective rights to know and understand the agroecosystems we work within and around (de Molina et al., 2019).

As food and farming systems have modernized, knowledge about them has been increasingly displaced. Modern agricultural technology packages have shifted entire regions toward monocultural export-oriented farming and displaced peoples through processes of de-peasantisation and the capitalist reorganization of agrarian relations (Pimbert, 2018). This is reflected directly in the steady shrinking of the agricultural workforce itself (Mortan et al., 2016): as farmers have been pushed off the land, the knowledge they once held about that land has been displaced or lost altogether. With the so-called "green revolution," for example, the need to know how to harness local sources of fertility became essentially redundant, with the option to "buy in" chemical fertility from the industrial system. While this approach had some short-term benefits in terms of yield [though these gains too have also been found to be overstated (Freebairn, 1995; Stone, 2022)], it resulted in serious long-term harmful impacts. These negative ramifications were in part because of a knowledge paradigm that craves uniformity and struggles to accommodate the radical specificity and diversity of agroecosystems (IPES, 2016). In short, the paradigm of industrial agriculture has rapidly eroded essential reservoirs of ecological knowledge and practice that have sustained humans for millennia (Pimbert, 2018).

Agroecology is often said to be knowledge intensive rather than input intensive. Indeed, much of the policy around agroecology—and sustainable food systems generally—acknowledges this challenge; that is, a one size fits all approach cannot work, and that farmers and local actors are better positioned to create and develop knowledge about the systems they work in (Pimbert et al., 2021). Over the last three decades, there has been a significant increase in calls to develop a range of processes which reintegrate farmer and local actor perspectives, from multi-actor research platforms [Like EIP-Agri (see Comegna and Sidorini, 2016)], farmer-centered research projects [like Prolinnova (see Birke et al., 2016)], farmer-to-farmer networks [such as those championed by La Via Campesina (Rosset, 2013)].

While they all acknowledge the same problem, farmer participation in research spans a wide range of different practices, which, moreover, reflect contrasting models of knowledge production and farmer and local actor agency. In some cases, farmer participation in research is narrowly conceived as a way to increase the uptake of agricultural technologies among participants (e.g., Hellin and Camacho, 2017). In other cases, farmer participation in research is presented as part of a fundamental strategy toward food sovereignty and agrarian reforms (e.g., Coolsaet, 2016). While the language can easily overlap, the worldviews here are often fundamentally at odds.

This paper sets out to explore what farmer participation in research means from an agroecological point of view. What degree of participation is desirable or even practical to expect from farmers? Should everyone be paid for their time? Can farmers design and implement their own research or do they always need to collaborate with professional researchers? How should decisions be made? And ultimately whose agency, whose interests, and what ends are prioritized?

In pursuit of these questions we first review the literature on farmer participation in agroecological research, situating it in a broader set of emergent participatory research methodologies. We then present three case studies featuring a variety of different forms of farmer (and other non-academic) participation in research. While each project is rooted in a different context and operating at different scales, they share a common commitment to building partnerships through the co-production of knowledge for food system transformation. In each case, a description of the knowledge co-creation processes is presented through an analysis of a range of materials (interviews, questionnaires, and field notes).

Out of these three cases we offer new insights into farmer participation in research conducted in the context of the agroecological paradigm, as well as some of the key challenges and future research trajectories of doing such work. In particular, we offer a critical reflection on the role of the researcher in such initiatives. The article concludes by offering a schematic (Figure 2) of the dynamics of knowledge production and participation in research processes which we hope will be useful to researchers interested in exploring research co-design.

2. Background on farmer participation in the co-production of knowledge

2.1. Farmer participation in agricultural research

Aside from the now widely recognized fact that farmers have always in a sense "participated" in research through their own on-farm experimentation and countless generations of "trial and error" (Rosset, 2013), more formal farmer participation and collaboration with academic research organizations has itself a long history. As the industrial agricultural research sector grew through the 1940's and 50's it became increasingly important to be able to sell "technology packages" being developed by agribusiness and promoted through research and development organizations. So began a process of formally involving farmers to "improve" this process, sometimes referred to as the "transfer of technology" approach (Sontakki and S. P, 2017; Challob et al., 2020).

Over time, these processes have tended to become more "participatory," as recognition has grown about the benefits of more substantially involving farmers in Research and development process (Pansera and Owen, 2018), sometimes referred to as the "participatory turn" in research practice (Irwin, 2001). Through outreach efforts like the "training and visit system" there emerged the framework for the modern agricultural extension system (Hayward, 2019). In general, the trend has been toward spatial decentralization (while maintaining centralized "intellectual" control); for example, farms have always provided useful testing

grounds for applied research with added benefits of "ground-truthing" research products (Chambers, 2021). Such an approach is now standard practice for Research and Development in many mainstream research organizations.

Alongside top-down models of farmer participation in research there have been prominent examples of more bottom-up research. Here the research methodology has tended to be more substantially about increasing farmer autonomy—especially from the hostile environment of corporate agriculture—but also often with some degree of NGO or researcher support. These initiatives tend to be Global South focused, drawing on much larger peasant farming communities compared to the Global North (see Rosset et al., 2019). Notable examples include the emergence of "*campesino a campesino*" horizontal method in Guatemala in the 1970s, and the "political-agroecological training schools" promoted by La Via Campesina from the early 1990s (McCune and Sánchez, 2019).

More recently, organizations like ANAP in Cuba have continued this legacy, demonstrating what Holt-Giménez (2009) calls the "most dramatic success stories" of "farmer-driven agroecological" innovation, helping the entire country transition to low-input, small-scale systems in the wake of the collapse of the USSR (Holt-Giménez et al., 2010). These successes were in no small part due to a deliberate inversion of the dominant top-down paradigm of research, when ANAP "decided in 2001 to reduce its dependence on external financing and technical advisers, and transformed CAC into a movement among the organization's members" (Rosset, 2013). Though Global South focused, these movements have remained a powerful store-house of influence and inspiration to related movements in the Global North (Anderson et al., 2018).

Given this long and complex history, a huge diversity of different agricultural practices have been the focus of research participation. In the literature, many of examples are output-focussed; in particular, plant breeding (Njukwe, 2015) and varietal trials (Timsina et al., 2016) which due to its amenability for on-farm experiments, and farmer involvement has remained popular among researchers, often focused on yield, drought and disease resistance (Roschinsky et al., 2016; Adamsone-Fiskovica and Grivins, 2021). Others include transfer and adoption of specific technologies (e.g., Cook et al., 2018), irrigation systems (e.g., Uphoff, 2019), and techniques for climate change adaptation (e.g., Karanja et al., 2017).

Beyond technology transfer approaches, a growing number of studies have taken a more "farming systems approach" approach (Behera and France, 2023), looking at things like farmer participation in soil health monitoring (Head et al., 2020), water quality (Taylor and Van Grieken, 2015), as well as nurturing local and informal innovation processes (Djohy and Nchor, 2020), open-source digital tech development, as well as numerous studies which have sought to construct meaning with farmers about agricultural policy, the role of indigenous knowledge, and social movement building (Hellin and Camacho, 2017; Salembier et al., 2020; Richardson et al., 2021). Politics aside, in many ways farmer participation in research approaches are driven by a shared idea; i.e., that research must more accurately reflect the "real world," recognizing that innovation, research and development processes are complex and require input from multiple actors, and need to emerge iteratively and adapt to place.

Despite these commonalities there is still a pronounced tension in farmer participation in research in terms of how farmers participate, and how their agency is framed, echoing the historic bottom up/top-down binary, that Bakker et al. (2021) calls the difference between being "collaborative" and "consultative." As we have seen with mainstream processes, this has been about framing the farmer as passive—at best a consumer of products and packages that they must be convinced to buy, en masse. As such, many of these research projects only involve the farmer at very specific stages, often in order to get their opinion on prototype technology. By contrast, other studies have made substantial efforts to, as Gkisakis and Damianakis (2020) put it "rethink the roles of 'users' in [innovation] processes," by including them much earlier in the research process, and consistently throughout, so that research agenda can be shaped and iteratively developed by them as co-producers of research and knowledge. Here the researcher moves from being the knowledge "validator" to a "facilitator" or at least a co-inquirer. Interestingly the divide is by no means polarized, with increased calls either for shared objectives to be recognized (Chambers, 2021), or where acknowledgment of mutual needs has emerged over time (Ashby, 1987; Bakker et al., 2021).

Despite enthusiasm for farmer participation in research, another commonality in the literature is the recognition of the complexity of such research dynamics. That said, how to hold this complexity is rarely specified. Indeed, the so-called "participatory turn" has brought with it the implication of increased cost, and there is a recurrent concern in the literature highlighting the lack of institutional and financial support. The upshot of this is that given the complexity and diversity of possible research contexts—and despite the interest in the literature—very little is known about how to do this research well, especially in a way that doesn't unwittingly reproduce power dynamics and/or result in low quality research.

2.2. Farmer participation in agroecological research

In the literature, agroecology is routinely described as an ideal context for high quality farmer participation in research. One of agroecology's central tenets is the "co-creation and sharing of knowledge" (FAO., 2023), which, as Gliessman (2018) puts it, is rooted in '[valuing of] all forms of knowledge and experience in food system change." Building on this idea, Coolsaet (2016) outlines what he describes as "an agroecology of knowledges"; that is, a counter-hegemonic engagement with modern agronomic science, through the recovery and co-production of situational, environment-specific knowledge, and the reskilling of farmers.

While agroecological researchers have explored specific practices for including farmers—integrated pest management (Deguine et al., 2021), tool design (Giotitsas and Ramos, 2017), plant breeding (Colley et al., 2021) are common examples—farmer participation in research in agroecology remains overwhelmingly focused at the level of principles (Altieri, 2016; Richardson et al., 2021). In many ways this is understandable, reflecting agroecology's emergent and counter-hegemonic status, especially when compared to mainstream research approaches. Moreover, the development of agroecological research practice has been further

hampered by low rates of funding (Moeller and CIDSE, 2020) and even aggressive push back against mainstream agricultural research (Vanloqueren and Baret, 2009). The under-development of agroecological research is deeply constrained by the mainstream politics of knowledge and the lock-in of the agro-industrial food system. Agroecological knowledge thus not only aims to improve agricultural science but to actively contest and transform the dominant knowledge regime—which may take decades, even centuries, to overturn (Levidow et al., 2014).

While existing agroecological research principles foreground cognitive justice, farmer inclusion and even being "farmer-led" (FAO., 2023), few attempts to systematize this process have been made, meaning we lack answers to many important questions. For instance, what extent of participation can realistically be expected of farmers given their different capacities? Is full farmer participation and involvement always good, or do different research objectives—and different types of knowledges involved—demand different degrees and modes of participation? For example, consider the different modes of participation and ways of knowing required by a large quantitative study involving many replicates over multiple locations, compared to studies examining cultural or traditional knowledge or field-scale trials emerging from locally specific needs. All (we would argue) are needed in the effort to research agroecology, and all require the input of farmers; however, they might each require crucially different skills and degrees of input from researchers and farmers. Exactly which knowledge and research objectives match with which mode of research participation remains poorly understood.

This gap between theory and practice in agroecological research has been known for some time. The often-cited paper by Wezel et al. (2009; p. 27) helpfully pointed out that agroecology operated in three main domains—as "a science, a movement and a practice" (SMP)—on the one hand pointing to agroecology's pluralistic and transdisciplinary DNA, while on the other indicating that these multiple domains were being used inconsistently and causing "confusion." It is telling perhaps that this paper has largely been taken up, not as an area to be worked on, but as a slogan for agroecology's multi-facetedness and transdisciplinarity (e.g., FAO., 2023). Instead, we argue the Wezel et al. paper represents some of the unfinished work of thinking about how to bring coherence to agroecology's multiple domains of knowledge and practice; that is, to think about how agroecological research creates knowledge and engenders participation based on different needs and objectives of participants (see Table 1). In this article, we return to this early three-part SMP framework to probe pending questions relating to the different modes of participation and ways of knowing involved in the co-production of knowledge for agroecological transitions and transformations.

As Wezel and Soldat (2009; p. 13) suggest, agroecology as SMP is a field "that integrates different disciplines to finalize a more systemic approach" to research, but that this work is "still under development." In order to better understand how *different types of knowledge and participation* are at play across these "different disciplines," which change and interact depending on their context, we present a schematic here (Figure 1). The schematic is built around two "axes"; first, from left to right, the schematic moves from "abstract" (i.e., generalisable and repeatable) knowledge to that which is more "applied" (i.e., experiential or place-specific

TABLE 1 Elaboration of the "science, movement, practice" framework.

Research dimension	What knowledge does it tend to emphasize?	What kind of participation is incentivised?
Scientific	• Abstract • Repeatable • Generalisable	• Large numbers of participants • Designed by 'professionals' • Passive participation
Movement-focused	• Relational • Process focused • Politically/socially relevant	• Medium to large numbers of participants • Designed by movement participants • Co-production/-design
Practice-focused	• Applied • Experiential • Place-specific	• Smaller number of participants • Validation by users • Active implementation by users • Co-production/-design

Source—Authors' own elaboration based on conceptual framework first set out in Wezel et al. (2009).

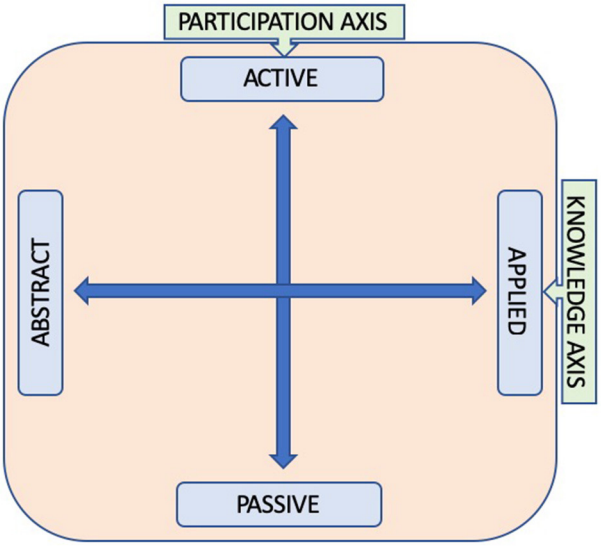

FIGURE 1
Dynamics of knowledge production and participation in research processes (simplified version). This schematic is a representation of the dynamics of knowledge co-production and participation in research processes. The lateral axis represents a spectrum of knowledge from abstract (i.e. generalisable and repeatable) to applied (i.e. pragmatic and experiential). The vertical axis represents the spectrum of participation from "active" to "passive".

rooted in a pragmatist worldview). This reflects what Creswell and Creswell (2017) differentiate as different research paradigms—one focusing on the production of knowledge that is useful in practice and adapted to place (pragmatism), versus knowledge that is created for generalizability to inform an abstract or "placeless" knowledge (rooted in a positivist research paradigm). This latter kind of knowledge can be useful in terms of developing academic theory and for policy-making at larger scales of organization (regional, national, international, etc.) and for cross-comparisons between places using standardized measurements. The former

knowledge (applied) is useful for learning, planning and developing practice in processes of agroecology transition on farms and in territories. As we will discuss later, Creswell and Creswell (2017) also delineate a transformative research paradigm that seeks to strategically combine these approaches and knowledges in an intentional orientation toward mobilizing knowledge for social justice and sustainability. This transformative research paradigm, we argue, is a vital concept to make sense of a more nuanced, contextual and strategic approach to knowledge co-production for agroecology.

The second axis—the "participation axis," which from top to bottom moves from "active" to "passive"—represents the degree to which the subjects of knowledge production (i.e., farmers, but also other groups) are involved in the co-production process. This axis is reflective of existing models that have been developed to characterize participation in public life, knowledge production and institutions. For example, Arnstein's (1969) ladder of participation presents a spectrum of participation from low ("non-participation") to high ("empowerment").

For both axes, we contend that there is not necessarily a normative directionality, but that each have validity depending on the specific needs and contexts in question. What is important, we argue, is that knowledge co-production processes are collective social processes rooted in commitments to progressive transformation of socio-ecological systems and cultures. There are strategic choices that are made, collectively, by those seeking to mobilize knowledge to deploy processes that are best suited for the situation at hand. Rather than saying full participation and specific knowledge are good and abstract and passive participation are bad, we argue for a more nuanced, situational, strategic position that transgresses these binaries.

In the analysis that follows this adapted framework is used as a lens for our three case studies to understand the different ways in which they enacted research participation and knowledge co-production. In the end we return to and update this framework considering our results and discussion.

3. Methods

This research focuses on three action research case studies conducted between 2018 and 2022 at various locations in England and Wales. The case studies were selected as examples of agroecological research to varying extents co-designed and implemented with farmer and/or non-academic participants. While this study employed a mixed-methods data collection approach, care was taken to ensure equivalence across the data and all case studies draw on the following data types (summarized in Table 2): field notes; surveys or feedback forms; interviews; and records of reflective processes with participants.

Data was initially gathered as part of the process of documenting the research process and of assessing the impact of the research activities. Semi-structured interviews ($n = 12$) were conducted by the first author with a mix of project participants and collaborators to understand the ways in which the research process had been experienced as either enabling or disabling. Surveys (for cases 1 and 2) were distributed and focus groups held (case 3) ($n = 109$) using similar questions to further understand the participant perspectives on the types of knowledge and modes of participation which were featured in the research. All data generated was then analyzed in Nvivo to examine the mode of participation and knowledge co-production expected, experienced, or intended by participants.

The SMP framework described above was used as a top-level coding structure to organize experiences into the three main domains of action for agroecology (elaborated in Table 1). The framework was adapted slightly for the purposes of this study by adding in each case an assessment of whether participants found the experience "disabling" or "enabling." Following Anderson et al. (2019) we consider "enabling" to denote factors that "support communities to self-organize in ways that reflect the principles of agroecology whereas disabling factors undermine the agency of niche actors to develop agroecology." As such, our analytical framework also foregrounds the enabling (or disabling) of a community of practitioners who, in keeping with agroecology's "integrative" aspirations, bring a wide range of different needs and objectives. This article thus contributes to the co-design of agroecological research, in all its forms.

4. Case study descriptions and findings

In this section, we briefly describe each case to provide an overview of the context and objectives (Table 2). While each case was rooted in a different context and operated at different scales, they shared a common commitment to building partnerships through the co-production of knowledge for food system transformation. The results are presented using a similar structure in each case with a short summary followed by material from each of the three aspects of the SMP framework.

4.1. Case study 1: bioindicators pilot study

The Bioindicator Pilot Study was a research project commissioned in 2021 by members of The Landworkers' Alliance, facilitated and delivered by the Centre for Agroecology Water and Resilience (CAWR) and the Organic Research Center. Its main aim was to use four on-farm research activities (three in England, one in Wales) in order to better understand (a) the reliability of non-crop plant bioindicators (i.e., "weeds") as a soil diagnostic tool; and (b) the suitability of bioindicators as a tool for use by farmers in arable systems. While the research design was very much researcher-driven, farmer guidance and participation were central, with four fieldwalks used as a way to gather participant feedback and iteratively develop plant bioindicator methodology. Following the fieldwalk activities, a farmer field guide to plant bioindicators was developed and distributed (see Maughan and Amos, 2022 for link to guide). Due to its balance of abstract knowledge (i.e., the existing research on plant bioindicators) and pragmatic/applied knowledge through the farmer's field guide, as well as its moderate levels of participation we have placed this case study close to the center of our elaborated schematic (see Figure 2). This reflects the needs of the participants for research outcomes and processes which could be easily navigated by non-specialists while also remaining rigorous and adaptable to their contexts.

TABLE 2 Summary of case studies.

Case study name →	Bioindicators pilot study	Farm hack UK	Field learning
Period of research	2021–2022	2019–2021	2018–2020
Research themes	Non-crop plants ("weeds") as a soil diagnostic tool; Bioindicators; Soil testing	"Appropriate Technologies"; Open-source technologies; Knowledge commons	Field trial methodology; Biodynamic soil amendments; Biodiversity
Key partners	The Landworkers' Alliance Centre for Agroecology Water and Resilience (CAWR) Organic Research Center	Farm Hack UK The Landworkers' Alliance CAWR	Torth y Tir (TyT) CAWR
Initiator	Landworkers' Alliance	Farm Hack	TyT
Outcomes	Field guide Four workshops	Farm Hack Report Four Farm Hack events	Research findings report AGM report [in person]
Numbers of participants	93 (over four workshops)	590 (across 11 events)	20 (over 2 years)
Gender of participants (based on surveys)	Male (44.4%) Female (50%) Other (1.9%) Not stated (3.7%)	Male (38.5%) Female (48.7%) Other (5.1%) Not stated (7.7%)	No data
Survey respondents	54	43	12 [2 focus groups]
Interviews	5	6	2
Research participation typology	Researcher-led	Participant-led	Participant-centered

4.1.1. Movement

Of those surveyed, 83% strongly agreed or agreed that "Overall my experience of the *Bioindicator pilot project* was positive," suggesting an enabling environment for knowledge sharing and participation. After coding, interviews revealed a similar picture with respondents identifying majority enabling experiences. This was particularly the case for movement knowledge – i.e., knowledge and skills in terms of collaboration, networking, relationality. For instance, 72% of those surveyed were to "a great extent" or "somewhat" more "likely to engage in farmer-to-farmer knowledge exchange activities." Interview respondents highlighted post-event networking, the collaborative skills foregrounded and required, and the strong sense of trust and connection that came from "different way of doing research" in particular they "enjoyed eating [together] and building trust that way."

Despite many indicating they would seek out more "farmer-to-farmer" activities, this did not appear to develop directly from the events themselves, with more than half (58%) reporting that they had either to a minimal extent or "not at all" "kept connections with other participants I met on the day" compared to 32% who had to "a great extent" or "somewhat." Indeed, interviews respondents also highlighted a number of barriers to network development including (on one field walk) there being not enough farmers present to make connections, or—conversely—feeling like farmers themselves wouldn't be interested if they weren't farming: "my work is ecological surveying, I would like to think that farmers would hear my knowledge but I am not from a farming background."

4.1.2. Practice

The Bioindicators project was strong in terms of its translation into individual practice, with 74% of respondents having "somewhat" or "to a great extent" increased their visual monitoring and assessment of the land they manage. Some accounted for this by pointing to the fit between the Bioindicator method and their "continual refinement of agricultural management techniques," and that it was easy to "to take back to my setting," with another suggesting the process left them with "practical learning of useful tools that could be immediately implemented back in situ." That said, some had a different experience, saying it was hard "to remember all this knowledge" and yet another reporting that "scoring system [was] not useful" and that their understanding of the bioindicator interpretation got "somewhat lost in the process." Overall, however, it was clear that there was a widespread hunger to learn about non-crop plants and use them as a tool for "reading the landscape," particularly as an easier and more accessible alternative more technical and lab-based testing. This may have been responsible for sending participants away with a renewed enthusiasm for playing a more active role in monitoring the lands they manage. As one respondent put it

> It has made me view weed species in a different way and sparked an interest in what the weeds may indicate about the farming system and soil [. . .] This was a great project to start engaging people in weeds and unwanted species and what they might mean—much easier than sending off soil samples and lab testing!

4.1.3. Science

While many could see the application in their own work, this may have been in spite of rather than because of rigor and coherence afforded by the process in terms of scientific knowledge production processes. Indeed, despite many reporting they were able to adapt methods to their context, a comparatively few ended up using the method itself (41% little/not at all compared to 50% somewhat/a great deal). Indeed, while some reported enabling elements such as learning "the basics of doing a field survey" or of appreciating increased botanical knowledge, more respondents mentioned aspects that were disabling of participation, including fears about precision, absence of details on soil health,

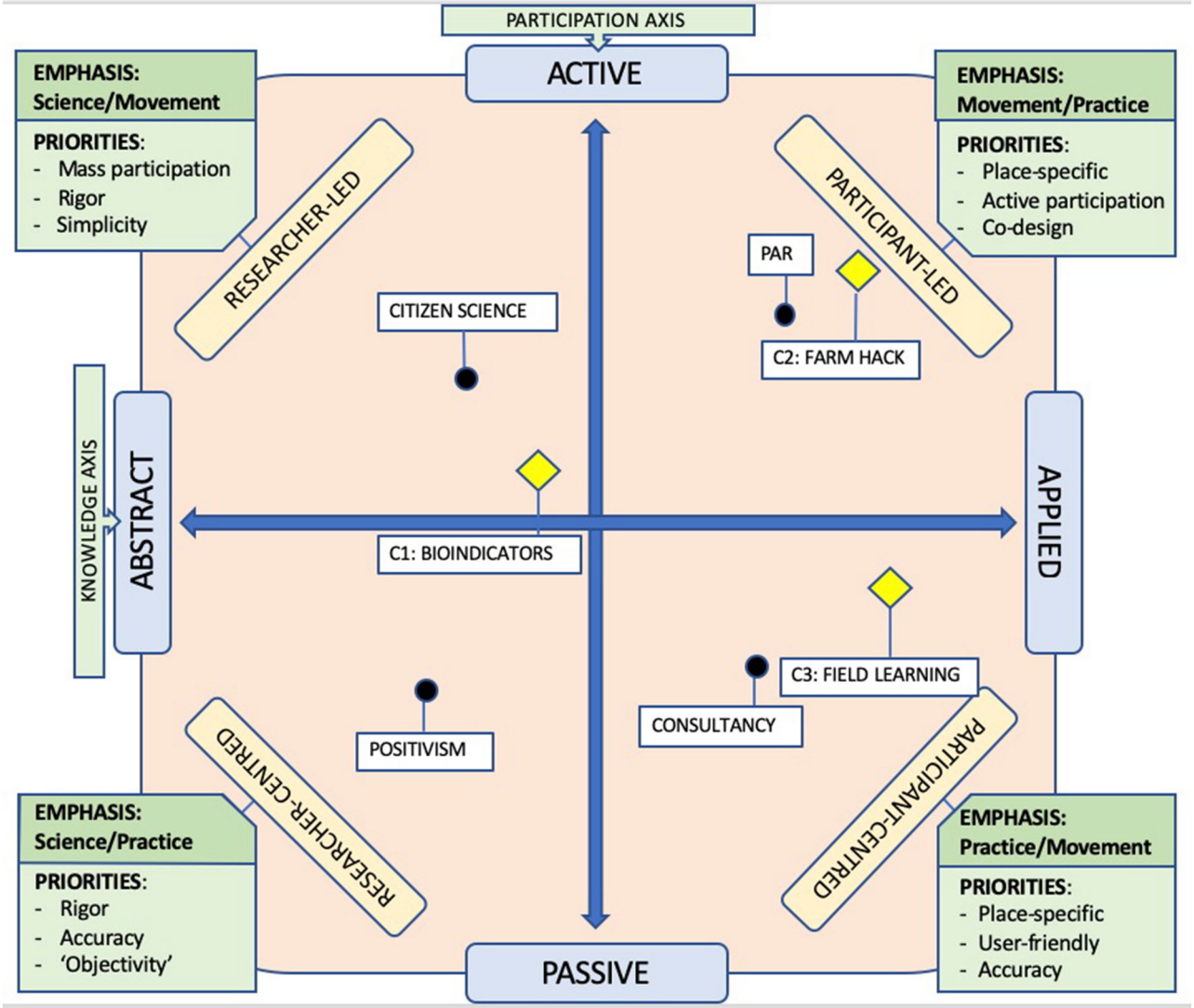

FIGURE 2
Dynamics of knowledge production and participation in research processes (elaborated). This schematic is elaboration of Figure 1 based on case study findings. In additional to the dynamics outlined previously, the schematic now delineates a four-part typology of researcher-participant interaction (described in detail above) and the related research "priorities" which each typology tends toward. The schematic also locates (using a yellow diamond) the three case studies (C1-3) alongside a series of other well-known research paradigms (i.e. positivism, citizen science, PAR, etc.). Though they are marked with a single point, each one of these occupies an approximate location.

and difficulties with the "rather lengthy meeting due to the number of assessments." Interestingly some respondents appeared to blame themselves for technical shortcomings, saying, "[I] didn't know enough plants for it to be practically useful by myself back at the farm. I need to learn more."

Overall, the bioindicators project appeared to succeed in creating an enabling environment for movement- and practice-based knowledge, catalyzing connections between and development of practices among participants. It was less successful perhaps in terms of its promotion of scientific knowledge and participation; that said, this could have been due to the underdevelopment of the science of plant bioindicators itself. Enabling participation of this kind of knowledge production may be challenging when methods are not set and evidence not yet fully established.

4.2. Case study 2: farm hack

Farm Hack first came to the UK in 2015 and (at time of writing) a further twelve events have been held, including two Soil Hacks and three Lady Hacks (aka "The Women's Farmworking Weekend"). In the UK, Farm Hack describes itself as "a collaborative network of farmers for more sustainable farming" (website, n.d.). Farm Hack advocates a "commons" approach to knowledge, focusing on skill-shares aimed at new entrants, and the development and promotion of "appropriate" and non-proprietary technology. Farm Hack is included in this study mainly for its focus on tool development, which is done often in a trial and error manner, but also because of its emphasis on knowledge co-production, which, in line with agroecological principles (Utter et al., 2021), is understood to happen in a distributed and

radically situated process. In short, Farm Hack provides a rare and compelling example of the co-production and systematization of new knowledge developed "on the ground," routinely without the help of formal research institutions or methods.

Organisationally, Farm Hack is decentralized with new coordinating groups independently organizing "hacks," which in many cases are built around sharing experimental tool designs, agroecological knowledge in general, and fostering discussion and networking of various kinds. In some cases, the events are used to advance collective knowledge by co-building a new tool, or modifying existing ones. The first author has attended numerous Farm Hack events since 2015, contributing in various ways to the organization and delivery of the events themselves, and with one event (2019) being substantially involved in the design and coordination activities. In 2020 the first author of this article co-led a systematic review of the Farm Hack UK network to assess its development and impacts to date and what scope it had to improve in the future. In terms of its position on the knowledge and participation axes (Figure 2), we placed Farm Hack toward the top right. This reflects the needs of the participants for research outcomes and processes that are adapted to place and which maximize participant autonomy.

4.2.1. Movement

Overall, we found that respondents reported resondents reported an enabling environment for participation and knowledge exchange. Overall, 85% of those who attended Farm Hacks observed an impact in a specific area of their practice and 95% said they are planning to attend another event in the future. This was particularly true in terms of movement knowledge and participation: Of those surveyed, 88% reported feeling better connected with other farmers and growers through developing social connections and networks with others around a common purpose. A similar picture emerged from interviews and written responses, which highlighted the powerful catalyzing effect of events, strengthened social networks, as well as a strong sense of collective knowledge and participation, leading to political and organizational knowledge:

> "The most important thing that I found was that I was not alone in trying to solve these problems. Being able to work with people afterwards is something that I value, as it means that Farm Hack is not a single event, but a constant process, just like the farming we do."

Despite this enthusiasm, a number of areas were highlighted as problematic including communications before and after events, a lack of participant diversity, and especially shortcomings in terms of co-design and facilitation processes. As one participant put it "by far the biggest challenge is the post-event level of community facilitation that's needed to maintain that energy, and people's willingness to contribute to this process." Another participant suggested the "high workload, low income for organizers and or a lack in sufficiently skilled facilitators" contributed to these shortcomings.

4.2.2. Practice

In terms of practice, there was a clear sense of the advantages of Farm Hack in terms of its practical focus, resulting in industry specific research processes:

> "As a direct result of being able to consult with 15 market gardeners at Farm Hack Wales I was able to gather evidence that [an] original [design] brief needed to be changed [...] This process was directly helped by a specific problem solving discussion at Farm Hack Wales, with a lot of direct advice and help from farmers who are interested in improving the kit and design systems of their farm and as attendees of Farm Hack Wales were motivated to help and advise."

In terms of participation, some respondents highlighted disabling aspects such as remote location, poor public transport, and inconvenient time of year for farmers and growers. And while some loved the practical format and content element, this could be uneven, and, depending on the skills of the facilitator, could be "challenging to involve everyone from start to finish on a project."

4.2.3. Science

With Farm Hack, abstract, scientific knowledge production processes didn't feature heavily. Many highlighted things they had learned about, though didn't provide much detail. One exception to this was concerns about co-design method, especially whether it could be easily documented as a means to link Farm Hack events. As one respondent put it, there should be "More emphasis on writing down method from a build project, so participants could have a plan to build their own [...] They should have proven designs More of them and better integrated into the process of documentation and links between each farm hack."

Overall, the image that came through was a thriving participant-led network with emphasis not necessarily on abstract or even practical outcomes but rather the relational aspects of movement capacity building. That said, being participant-led and decentralized the delivery of this was sometimes uneven and in need of improvement.

4.3. Case study 3: "field learning" project

The final case study, the "Field Learning" project, formed in 2018 as a way to explore how to engage in and co-produce agroecological knowledge on a community-supported farm. The focal point for this project was the "community supported bakery" Torth y Tir (TyT) which was searching for ways to engage members and other local growers in the collective governance of the farm. Following a participatory process, the group opted to use the framework of a "participatory field trial" (i.e., a field-based experiment planned and implemented by a large group of people) as a way to focus their investigation. With researcher support, the group then co-designed and implemented the field trial which examined the impact of a biodynamic soil amendment on marketable yield of the wheat crop and in-field biodiversity. In terms of its position on the knowledge and participation axes (Figure 2), we placed "Field Learning" toward the bottom right

of the schematic due to its place-specific knowledge objectives involving relatively passive participation. This reflects the needs of the collaborators for research outcomes and processes that are adapted to place but which did not put too onerous demands on participants.

4.3.1. Science

Attendees during two focus group sessions identified roughly equal numbers of enabling and disabling elements. Unlike the previous two case studies, Field Learning participants tended to highlight the advantages in terms of scientific knowledge production processes. For example, respondents noted in particular the benefits of having a year-long experiment to structure meetings throughout the year, the benefits of having a researcher to help with experimental design, but also to help facilitate the process in general. While not always a feature of scientific enquiry, participants particularly found the process of completing a planned process and getting "positive results" enabling: "We completed the experiment as planned and got some positive results [...] it was a success, we put time in we created a group and we did the experiment and that first year."

Some disabling aspects were highlighted, however, especially the technical demands of data collection, not understanding the causes underlying the results obtained, or that "science" itself could end up displacing other ways of knowing:

> "when you say the word 'science' and you know . . . it's more powerful than the word God it seems and and, therefore, and therefore yeah it just naturally seems to sort of take up the space in the middle."

4.3.2. Movement

Enabling elements of movement knowledge production processes included a strong sense of connection, collaboration generated by the research process. Respondents highlighted the way the process reduced the "isolation" of farmer participants, and that it really was "the relationships between the farmer and the researcher is what makes it work." Beyond this, one respondent also noted the power of a collaborative process which brought people into the usually *un*-peopled agricultural space:

> "I don't know, culturally and in the cultural context within it, within which this was set and getting people onto a wheat field, which is something you normally just drive past [...] To do something like this is really quite radical."

Field Learning was generally felt to be more disabling in movement terms. While many enjoyed activities themselves, many cited problems with maintaining connection and communication between events. Respondents also cited that as time went on there was a need to "reach out to more farmers and growers to get more involvement," and a few others citing "geographical distance" and that it "would be nice to see wider involvement locally." Others noted the role that "technical aspects left to the facilitators/scientific advisers" resulted in an urgent need for "more sense of shared responsibility."

4.3.3. Practice

Like the movement category, Field Learning was also generally considered to be more disabling than enabling in practice terms, with respondents citing elements such as fitting in attendance around the growing season, accessing the farm from far away, overly technical procedures, with one respondent (the head grower at the farm) saying "I did find later on when the bakery was up and running and I have less time that it became more of a demand to be able to participate, because the economic ax was swinging over my head." Furthermore, this consolidated the sense that the project couldn't have happened without researcher support: "the amount of chasing people and arranging dates and following up on emails and stuff is just too much as I'd say for a farmer."

That said, in practice terms having a researcher-led process did mean that "stuff got done," with many participants citing "learning new skills" in the field, being given space to experiment when normally farmers are just "someone that gets on with [farming]," rather than engaging in research. Most enabling of all though was the payment for the host farmer's time and resources used: "we wanted to [participate] but nonetheless we still had to be [financially] viable, viable, so [...] that you can reimburse them that time was essential really."

Overall, Field Learning was a successful project which introduced the basics of bio-physical agroecological research practice to participants. That said, there were clear trade-offs between delivery (which was researcher-driven and led) and the project's ability to engage participants in processes of collective learning and capacity building.

5. Discussion

The co-production of knowledge for agroecology involves a wide range of approaches, practices and knowledges that reflect the breadth of agroecological practice and knowledge itself. Across the three case studies, it was clear that the context (i.e., the objectives, needs, capacities, etc.) of research participants varied substantially and engaged in different ways with three types of knowledges—those that emerge from practice, from social movements and from scientific procedure. While each case was overall successful in its aims, the results revealed issues that could be addressed to increase the efficacy of knowledge co-production for agroecology transitions. These issues, described in the next sections, are not only specific to these cases, but are present in agroecology research practice generally where participants must contend with the particular context and the relational nature of co-production of knowledge as a social process.

5.1. Governing resources equitably

How resources are allocated for research and knowledge work is highly uneven in multiple ways. Firstly, at the project-level, agroecological research can be more expensive to implement than conventional research. Use of participatory methods, for example, often entails remunerating longer durations of "staff" or participant time. While extensive active participation of participants is not always possible—or even desired—taking seriously the resource

needs of participants will likely lead to better quality research outcomes, and ultimately a better fit between scientific, movement and practice dynamics. In some of our cases, the research wouldn't have been viable without paid time for participants, most notably with Field Learning (Case 3). Moreover, many of the disabling aspects identified by participants from the other cases could have been addressed with more resource, such as funding to subsidize costs (like travel and subsistence), but also training to deal with the challenges of co-delivering agroecological research. As one respondent put it, it can be "more challenging to create and work with people to have a more participatory free flowing type of agenda" or "Introducing people into co-creating design process." This is consistent with the theorisation of participatory research which begins from an acknowledgment that all knowledge and expertise are widely distributed, partial and situated (Fine, 2008) and therefore require more involved processes of research design.

In particular, having funds to pay for facilitation training (or alternatively to pay for external professional facilitators) was a shared concern across the case studies. As other research practitioners have demonstrated (Geilfus, 2008), the more participatory the research, the more important "process" becomes. Indeed, the participatory element in agroecological research is often seen to be at the heart of its political intent, requiring what Kindon et al. (2007) call the "iterative combination of critical thinking, and a jointly agreed normative orientation for action"; it is this extensive process "that gives the research its potential for emancipatory socio-ecological change."

Secondly, beyond individual research projects, agroecology research in particular is structurally marginalized in agricultural knowledge and innovation systems. For example, a recent study found that between 0% and 2.7% of funding from the EU for agricultural funding to the U.N.'s Rome based agencies went toward agroecological projects (Moeller and CIDSE, 2020). While each of our case studies aimed to produce knowledges important in processes of agroecology transition, none of them had access to any significant source of public funding. In fact, the authors of this paper co-applied for a grant to the European Commission EIP-Agri program to support the expansion of Farm Hack. The EIP program was intended to support multi-actor groups to foster competitive and sustainable farming and forestry that 'achieves more and better from less' and grants are awarded to tackle a certain (practical) problem or opportunity which may lead to an innovation. However, in practice these programs privilege the translation of scientific knowledge into practice, setting Farm Hack (focusing primarily on practical and movement knowledge) at a distinct disadvantage. Furthermore, these programs are rooted in a neoliberal market understanding of innovation (Anderson and Maughan, 2021) that can easily erase the value of movement knowledge and displace practical knowledge that doesn't conform to the prevailing model of productivist profit driven innovation. It is important to acknowledge this as it often makes the already difficult work explored in this article much harder, making our collective efforts at movement building across research contexts and communities an indispensable part of agroecological research and knowledge co-creation.

5.2. Adapting to changing roles and responsibilities

Agroecology represents a fundamental paradigm shift in the way we think about our food and farming systems—and this is no less true of the co-production of knowledge and research in agroecology. Some of the central operating principles of knowledge co-production are (*inter alia*) holism, place-specificity and the co-existence of different ways of knowing (HLPE and FAO, 2019). This often means that the researcher, like the agroecological farmer, must be able to adapt to context and fulfill a wider variety of roles than they have historically. As already discussed, the remit of these roles will depend on the particular research approach in use (see Figure 2), though a key role highlighted by the case studies was the "researcher as facilitator." The prominence of this role has of course to do with the specific needs of those involved, where—as represented on the elaborated schematic (Figure 2)—three of the four researcher roles have to do with channeling less what the researcher wants, and instead focuses on the capacities and interests of research participants.

The importance of facilitation highlights again the importance of the co-production of knowledge as a *process* as much as an outcome. The success of a research project can, in short, depend on the skills and (as one respondent put it) "the strength of the facilitator," with many respondents pointing to shortcomings in this area. This is especially true when the co-production process involves high relational investment to negotiate the different forms of SMP knowledge at play. This research revealed that facilitation must be understood to encapsulate a wide variety of research and design processes, such as including participants in research design, in particular using "iterative" processes to continually identify and update participant needs, and building them into the overall research method.

Across all case studies, despite being explicitly farmer-focused, all groups were made up of participants from different backgrounds (e.g., researchers, extensionists, technology specialists, community organizers, and artists). This was an organic feature of the research, emerging from participant input, reflective of the idea of creating a "*dialogo de sabers*" (wisdom dialogues) and the principle of involving the "most affected" now commonplace in the praxis of food sovereignty (Chappell et al., 2013; Maughan et al., 2020). The co-production of agroecological knowledge is thus not necessarily about exclusively researcher-farmer interactions, but instead the interactions between many different kinds of food systems actors. Interestingly, respondents sometimes expressed unease around this new proliferation and diversity of roles, either noting the lack of farmers or, conversely, fearing rejection by farmer-participants. This, we suggest, is indicative of a frontier for agroecological research, which must be overcome if it is to deliver on its "integrative" aspiration; as one respondent put it "Being the best possible farmer is not something you can do on your own [...] agriculture is not just an individualistic rural enterprise—it is *a shared human endeavor*." Researchers must be prepared for this by accommodating different perspectives, abilities, and needs through varied activity design.

While shared, this responsibility sits substantially with a paid researcher—often they are the de facto mediator, "principle

investigator," and facilitator, and even in genuinely farmer-led processes they will need to adapt to multiple roles, many of which aren't traditionally in the wheelhouse of the researcher. There are many advantages here, not least disruption of the out-dated binary of "researcher and researched." While desirable, there is also a burden of responsibility that comes with this that must be tempered with a searching reflexivity. If not addressed, in these less widely practiced modes the research may unwittingly reproduce errors of traditional research, not least forcing participatory processes when they are not appropriate or desired.

5.3. Foregrounding of movement-focussed objectives and processes

One of the most important findings of this study was the preponderance of participant interest in what we describe as "movement-focussed" research dimensions, meaning: (a) the relational and collaborative dynamics significant to movement building and (b) the importance of research emanating from collective processes of strategizing and mobilizing for change. As is evident in the literature on the co-production of research (e.g., Utter et al., 2021), in processes that privilege the science and practice dimensions of agroecology, research is often detached from social processes of change and thus typically privilege the priorities and methods of science and productivism. In each of our three cases, an intentional and systematic collective process was planned, intended to respond to the priorities and aspirations of collectives working toward transforming food systems and society in each of the three projects.

While there is a risk in the practical and scientific epistemologies being detached and overpowering "movement knowledges," it is important to acknowledge the vital interaction between the knowledges of movement, science *and* practice for achieving a transformative knowledge co-production process. All case studies in this article had a primary practical focus; in each case, this was done deliberately to engage participants, but there was also always a political component present. Many participants reported attending for practical content or scientific knowledge, and leaving valuing a much wider set of benefits. Indeed, as one participant put it, the political and the practical dimensions can be mutually reinforcing:

> the can-do attitude combined with very practical focus leaves me feeling fired up at the end of the event rather than drained from trying to absorb an excess of theoretical knowledge (as I would after a conference or purely political meeting)

This does not mean that agroecological knowledge co-production can't be expressly political (there are many examples of purely "political" agroecological research), but there are important pragmatic considerations. As Rosset (2013) says, "for farmers, seeing is believing"—having a practical focus for research can be a useful way to attract farmer (and we would argue other non-academic) participants. Again, designing research processes with the SMP framework (Wezel et al., 2009) in mind can be a way to weave these multiple strands. Even the most ostensibly technical research focus presents political opportunities, and this was rarely lost on participants, especially where they were given space to discuss. As one participant put it,

> It is the conversations that happen around the lunch table that are often more important, so in the context of this well we don't just go to do the science we go to have lunch together *and* do the science.

Again, initiatives that focus purely on movement epistemologies are possible; however, where research starts from a practical focus this provides an important tangible and material anchor for participants. That said, political discussion won't happen on its own. At the very least, space must be left for participants to have these conversations, as a way to reflect on and process their experiences and dig into the "deeper" space of movement politics.

5.4. Balancing of trade-offs in research co-design

Despite agroecology's vast integrative aspirations, individual research projects can't be "all things to all people." Indeed, a prominent concern across the case studies related to the trade-offs inherent to research design. For instance, there were certain objectives normally associated with "conventional" (or what we call "researcher-*centered*") research which were in evident opposition to other objectives more common in agroecological research. For example, the pursuit of "rigor" or "objectivity"could easily result in the needs of participants being deprioritised by selecting methods which proved to be too onerous (or "boring") to reliably engage participants in the long-run. One emergent dynamic relating to this is the role of the collective in overcoming this: as one participant put it, they were really interested in doing the botanical surveys (Bioindicators—case 1) but wanted to do it "as a collaboration because it's boring by myself!"

Conversely, a collective approach can also present challenges for research co-design, as Farm Hack (case 2) repeatedly demonstrated. Across the cases, Farm Hack evidenced the greatest degree of strength and resilience, with evidence of an eight-year period of self-organized research, even in spite of the challenges of Covid-19. However, as many respondents commented, one of the "most difficult" aspects of Farm Hack design, was the need to balance many different factors, including unevenness in participant availability, experience, and geographical distribution. Participants highlighted challenges in facilitation and "connecting up the dots" between in-person events and documentation of activities and updated designs—something professional researchers can normally be relied on to manage. This trade-off says a lot about the challenges faced in scaling the co-production of knowledge in agroecology, which requires a careful balancing of the involvement of professional researchers in such a way that doesn't inadvertently create dependence, undermine active participation, and distort research agendas through the pursuit of funding.

More than simply stating that agroecological research is complex and difficult to scale, the point here is that given this

complexity it makes sense to think about how to contend with these varied (and sometimes competing) dynamics to maximize the efficacy of these processes in affecting change in agroecological transitions. This will require researchers and other actors involved in knowledge co-production to take a reflexive approach and develop a repertoire of tools, such as research diaries, formalized critical friendships (Anderson et al., 2022), ample space and varied venues for feedback, and opportunities to act on feedback.

5.5. Mapping out researcher-participant interactions

In this section, we build on the above discussion by returning to the schematic presented at the beginning of the article (Figure 1). We map out the cases studies and other processes of knowledge co-production across the two axes (abstract-applied knowledge production; Active-Passive participation in research process). This elaborated schematic (Figure 2) helps to visualize the commonly held position that agroecological research should acknowledge multiple forms of *knowledge* and types of *participation*. Accordingly, the schematic is built around two "axes"; first, from left to right, the schematic moves from "abstract" (i.e., generalisable and repeatable) knowledge to that which is more "applied" (i.e., experiential or place-specific); second, the "participation axis," which from top to bottom moves from "active" to "passive." These two axes then give rise to a four-fold typology of researcher-participant interaction which is as follows:

> "Researcher-led"—research is largely designed and carried out by researchers, but requires the active involvement of participants.
>
> "Researcher-centered"—the needs of the researcher (i.e., rigor, accuracy, repeatability, etc.) are prioritized over the needs of participants.
>
> "Participant-led"—the majority of work and design carried out by participants. Professional researchers may be involved, though are not essential to the work.
>
> "Participant-centered—research based on the needs and input of participants but mainly carried out by researchers.

The main implication of this schematic is that each type of research-participant interaction is more conducive to a certain set of priorities (listed in each corner). While these remain speculative (i.e., based on limited cases), we envisage that the schematic could be used to begin research co-design by identifying priorities relevant to the group and context in question.

While there may be a tendency for agroecology researchers to gravitate toward the top right quadrant due to its emphasis on participant autonomy, it is important to remember that the graph is value neutral—i.e., no research mode is meant to be "better" or "worse" than another. What is most important is that research projects emerge out of collective processes between researchers, affected communities and their organizations. In some cases, these collective processes may reveal that there is a need for large randomized control studies which are largely carried out by research professionals - for example, in the effort to build evidence for the efficacy of green manures in building soil carbon. In other cases, more small-scale and participatory processes might be more appropriate, as in the case of Farm Hack, designing and re-designing tools for those in specific cultural, economic and agroecological settings.

In short, this is to remind researchers to avoid inadvertently creating an agroecological research dogma based on the notion that every method used needs to involve the full participation of affected communities. This itself falls into the error of treating Participatory Action Research as a method, rather than as an approach that uses multiple methodologies and pedagogies rooted in a wider participatory social process. Within this context, a team co-producing knowledge should seek to deploy methods across the two axes (Figure 2), rooted in a transformative research worldview (Creswell and Creswell, 2017) to co-produce knowledge as a part of wider social processes aimed at emancipation of the human and more-than-human world.

Thus, the aim of co-production can be viewed within a process unfolding at much larger scales of space and time to both materially transform the food system (through action research) and to build what Montenegro De Wit and Iles (2016) call "thick legitimacy." This involves a process whereby agroecology gains credibility and authoritativeness as an alternative to the dominant mode of development and thus gain potential to displace industrial-corporate food systems. Importantly, "thick legitimacy" is not only derived from the production of better evidence and scientific knowledge, but through legitimation processes across the spheres of scientific, policy, political, legal, practice, and civic knowledges. Clearly, the knowledge needed to move toward agroecology will require knowledges across (at least) the three domains science, movement and practice.

6. Conclusion

"To listen is to lean in softly
With a willingness to be changed
By what we hear."
(Mark Nepo)

This article examined several concrete examples of knowledge co-production in agroecology with the aim of better understanding how to create a more, mutually beneficial, and inclusive research culture for the co-production of knowledge. We have argued that, though it is complex, it is not beyond our collective abilities to design and implement research in ways that don't oversimplify the world, or dehumanize or instrumentalise research participants. Critical in this process is an ability for researchers to listen deeply, while being embedded in collective processes of agroecology transitions, and to be willing and able to shift to meet the needs and priorities that emerge through these relationships. This is the wider process of knowledge co-production, viewed as a distributed but intentional social process to mobilize knowledge in action.

To aid researchers in positioning different approaches within this process of knowledge co-production, we presented a schematic (Figure 2) to help visualize these design processes, to recognize and accommodate the manifold contexts, needs, and capacities underlying the research within a co-production paradigm. Moreover, we hope that the schematic could provide a useful tool for researchers and participants (or co-researchers) alike

in the research design process, making visible common trade-offs, and assisting in the selection of the right approach for the given context. Using an adapted SMP framework we noted the largely unmet interest among participants in "movement-focussed" research dynamics, in particular the processes of co-design and facilitation that make collaborative research with diverse participants possible.

This research also raises important questions about how agroecological research moves forward, particularly in terms of how it reconciles high participant autonomy and the tendency toward context-specific research with attempts to communicate results to a global community. Agroecological research is no longer, as it was originally described, simply the study of the ecological dynamics in agricultural systems (Wezel et al., 2009). It is now informed by a radically different way of looking at the world, characterized by the co-existence and deep interrelatedness of multiple knowledges. This can make it hard for agroecology research to "fit" neatly into the mainstream scientific paradigm, which has its roots in an elitist, homogenizing, and reductionist world-view. Agroecological research must continue to find new ways to gather its many colorful strands, without also falling into the same epistemological traps.

The co-production of knowledge for agroecology holds up a mirror to the complexity of the web of life. This web is one within which we are all embedded, and, must, if we are to survive and flourish, be humble before. It demands, as the Mark Nepo quote above so eloquently puts it, that we must remain forever prepared to listen carefully and be changed by what we find in our inquiries. This research can be one of the most urgent, empowering and enlivening processes we can undertake together—like farming, it is a shared human endeavor in which it is our collective right to participate.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by Coventry University. The patients/participants provided their written informed consent to participate in this study.

Author contributions

CM conducted fieldwork, designed and distributed research instruments (i.e., surveys), and wrote up results and analysis. CA provided support at various stages of the write up process, as a well as with the development of the conceptual framework. All authors contributed to the article and approved the submitted version.

Funding

CM was supported by a British Academy Postdoctoral Fellowship (pf170070) to carry out this research.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Adamsone-Fiskovica, A., and Grivins, M. (2021). Knowledge production and communication in on-farm demonstrations: putting farmer participatory research and extension into practice. *J. Agricult. Edu. Exten.* 3, 1–24. doi: 10.1080/1389224X.2021.1953551

Altieri, M. A. (2016). Developing and promoting agroecological innovations within country program strategies to address agroecosystem resilience in production landscapes: a guide. Available online at: https://www.academia.edu/32092336/Developing_and_promoting_agroecological_innovations_within_country_program_strategies_to_address_agroecosystem_resilience_in_production_landscapes_a_guide (accessed July 03, 2023).

Anderson, C. R., Bruil, J., Chappell, M. J., Kiss, C., and Pimbert, M. P. (2019). From transition to domains of transformation: getting to sustainable and just food systems through agroecology. *Sustainability* 11, 5272. doi: 10.3390/su11195272

Anderson, C. R., and Maughan, C. (2021). 'The Innovation Imperative': The struggle over agroecology in the international food policy arena. *Front. Sustain. Food Sys.* 5, 9125. doi: 10.3389/fsufs.2021.619185

Anderson, C. R., Maughan, C., and Blume, S. (2022). Embracing Critical Friendship for Agroecology Transitions. Perspectives on Agroecology. University of Vermont. Burlington. Available online at: https://www.uvm.edu/agroecology/wp-content/uploads/2022/04/2_Critical-Friends_transition-brief_English.pdf (accessed July 03, 2023).

Anderson, C. R., Maughan, C., and Pimbert, M. P. (2018). Transformative agroecology learning in Europe: building consciousness, skills and collective capacity for food sovereignty. *Agri. Human Values* 3, 9841. doi: 10.1007/s10460-018-9894-0

Arnstein, S. R. (1969). A ladder of citizen participation. *J. Am. Inst. Plann.* 35, 216–224. doi: 10.1080/01944366908977225

Ashby, J. A. (1987). The effects of different types of farmer participation on the management of on-farm trials. *Agricult. Admin. Exten.* 25, 235–252. doi: 10.1016/0269-7475(87)90079-1

Bakker, T., Dugué, P., and De Tourdonnet, S. (2021). Assessing the effects of farmer field schools on farmers' trajectories of change in practices. *Agron. Sustain. Dev.* 41, 1–15. doi: 10.1007/s13593-021-00667-2

Behera, U. K., and France, J. (2023). Farming systems research: Concepts, design and methodology. In *Advances in Agronomy*. Elsevier, 177, 1–49 doi: 10.1016/bs.agron.2022.08.001

Birke, F. M., Zerfu, E., and van Veldhuizen, L. (2016). Assessing the institutionalisation of Participatory Innovation Development: A tool. *PROLINNOVA Working Paper 37*. Available online at: https://prolinnova.net/wp-content/files/documents/resources/working_paper/wp_37_pid_institutionalisation_assessment_tool_final.pdf (accessed July 03, 2023).

Campbell, B. M., Beare, D. J., Bennett, E. M., Hall-Spencer, J. M., Ingram, J. S. I., Jaramillo, F., et al. (2017). Agriculture production as a major driver of the Earth system exceeding planetary boundaries. *Ecol. Soc*. 22, 8. doi: 10.5751/ES-09595-220408

Challob, M., Lafta, A. H., and Ridha, B. (2020). Study on major constraints and problems in transfer of technology by agricultural extension organization. *Indian J. Ecol.* 47, 373–375.

Chambers, R. (2021). "Knowledge systems for inclusively responsible food and agriculture," *Rethinking Food and Agriculture*, eds in A. Kassam and L. Kassam. (Woodhead Publishing), (pp. 353–369). doi: 10.1016/B978-0-12-816410-5.00016-5

Chappell, M. J., Wittman, H., Bacon, C. M., Ferguson, B. G., Barrios, L. G., Barrios, R. G., et al. (2013). Food sovereignty: an alternative paradigm for poverty reduction and biodiversity conservation in Latin America. *F1000Research* 2, 235. doi: 10.12688/f1000research.2-235.v1

Colley, M., Dawson, J., McCluskey, C., Myers, J., Tracy, W., and Lammerts van Bueren, E. (2021). Exploring the emergence of participatory plant breeding in countries of the Global North – a review. *J. Agric. Sci.* 159, 320–338. doi: 10.1017/S0021859621000782

Comegna, E., and Sidorini, L. (2016). EIP-AGRI, innovation has a new approach. *Inform. Agrario* 72, 32–36.

Cook, S., Lacoste, M., Evans, F., Ridout, M., Gibberd, M., Oberthür, T., et al. (2018). *An On-Farm experimental philosophy for farmer-centric digital innovation*. 14th International Conference on Precision Agriculture, Montreal, Quebec. Available online at: https://researchportal.murdoch.edu.au/esploro/outputs/conferencePaper/An-On-Farm-experimental-philosophy-for-farmer-centric/991005543175007891 (accessed July 03, 2023).

Coolsaet, B. (2016). Towards an agroecology of knowledges: recognition, cognitive justice and farmers' autonomy in France. *J. Rural Stud.* 47, 165–171. doi: 10.1016/j.jrurstud.2016.07.012

Creswell, J. W., and Creswell, J. D. (2017). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. Sage publications.

de Molina, M. G., Petersen, P. F., Peña, F. G., and Capor, F. R. (2019). *Political Agroecology: Advancing the Transition to Sustainable Food Systems*. CRC Press. doi: 10.1201/9780429428821

Deguine, J. P., Aubertot, J. N., Flor, R. J., Lescourret, F., Wyckhuys, K. A. G., and Ratnadass, A. (2021). Integrated pest management: good intentions, hard realities. *A review. Agron. Sustain. Dev.* 41, 38. doi: 10.1007/s13593-021-00689-w

Djohy, G., and Nchor, J. (2020). Collaboration between farmer innovators and formal scientists in Participatory Innovation Development (PID). *PROLINNOVA Preliminary publication*. Available online at: https://prolinnova.net/wp-content/files/documents/thematic_pages/food_nutri_sec/proli-fans_farmer-scientist_interaction_280120.pdf (accessed July 03, 2023).

FAO (2023). Overview | Agroecology Knowledge Hub | Food and Agriculture Organization of the United Nations. Available online at: *http://www.fao.org/agroecology/overview/en/* (accessed July 03, 2023).

Fine, M. (2008). *An Epilogue, of Sorts. Revolutionizing Education: Youth Participatory Action Research in Motion*. London; New York, NY: Routledge, 213–234.

Freebairn, D. K. (1995). Did the green revolution concentrate incomes? A quantitative study of research reports. *World Develop.* 23, 265–279. doi: 10.1016/0305-750X(94)00116-G

Geilfus, F. (2008). *Tools for Participatory Development: Appraisal, Planning, Follow-Up and Evaluation* (No. 9290399104). San José, CR: IICA. Available online at: https://www.betterevaluation.org/sites/default/files/BVE17089190i.pdf (accessed July 03, 2023).

Giotitsas, C., and Ramos, J. (2017). A New Model of Production for a New Economy, Two Cases of Agricultural Communities. *New Economics Foundation*. Available online at: https://www.academia.edu/33661849/A_New_Model_of_Production_for_a_New_Economy (accessed July 03, 2023).

Gkisakis, V. D., and Damianakis, K. (2020). Digital innovations for the agroecological transition: a user innovation and commons-based approach. *Landbauforschung J. Sustain. Organic Agricult. Sys.* 2, 1–4.

Gliessman, S. (2018). Defining agroecology. *Agroecol. Sustain. Food Sys.* 42, 599–600. doi: 10.1080/21683565.2018.1432329

Gliessman, S. R., Méndez, V. E., Izzo, V. M., and Engles, E. W. (2022). *Agroecology: Leading the Transformation to a Just and Sustainable Food System*. Boca Raton, FL: CRC Press. doi: 10.1201/9781003304043

Hayward, J. A. (2019). "World Bank involvement in agricultural extension," in *Technology Systems for Small Farmers* (pp. 133–152). CRC Press.

Head, J. S., Crockatt, M. E., Didarali, Z., Woodward, M-. J., and Emmett, B. A. (2020). The role of citizen science in meeting SDG targets around soil health. *Sustainability* 12, 24. doi: 10.3390/su122410254

Hellin, J., and Camacho, C. (2017). Agricultural research organisations' role in the emergence of agricultural innovation systems. *Dev. Pract.* 27, 111–115. doi: 10.1080/09614524.2017.1256373

HLPE and FAO (2019). *HLPE: Report 14-Agroecological and Other Innovative Approaches for Sustainable Agriculture and Food Systems that Enhance Food Security and Nutrition*. Available online at: http://www.fao.org/fileadmin/user_upload/hlpe/hlpe_documents/HLPE_Reports/HLPE-Report-14_EN.pdf

Holt-Giménez, E. (2009). From food crisis to food sovereignty: the challenge of social movements. *Monthly Review*. Available online at: https://monthlyreview.org/2009/07/01/from-food-crisis-to-food-sovereignty-the-challenge-of-social-movements/

Holt-Giménez, E., Bunch, R., Irán Vasquez, J., Wilson, J., Pimbert, M. P., Boukary, B., et al. (2010). Linking farmers' movements for advocacy and practice. *J. Peasant Stud.* 37, 203–236. doi: 10.1080/03066150903499943

IPES (2016). *From uniformity to diversity: A paradigm shift from industrial agriculture to diversified agroecological systems*. International Panel of Experts on Sustainable Food Systems (IPES). Available online at: http://www.ipes-food.org (accessed July 03, 2023).

IPES food and ETC Group (2021). *A Long Food Movement: Transforming Food Systems by 2045*. IPES-Food. Available online at: http://www.ipes-food.org/pages/LongFoodMovement (accessed June 8, 2023).

Irwin, A. (2001). Constructing the scientific citizen: Science and democracy in the biosciences. *Public Underst Sci.* 10, 1–18.

Karanja, E., Kamau, G., Macoloo, C., Righa, M., van Veldhuizen, L., Waters-Bayer, A., et al. (2017). "Supporting farmer innovation to enhance resilience in the face of climate change in farming systems in Machakos and Kitui Counties, Keny,". in *Climate Change Adaptation in Africa*, (Springer), pp. 677–688. doi: 10.1007/978-3-319-49520-0_42

Kindon, S., Pain, R., and Kesby, M. (eds.). (2007). *Participatory Action Research Approaches and Methods: Connecting People, Participation and Place*. London; New York, NY: Routledge.

Levidow, L., Pimbert, M., and Vanloqueren, G. (2014). Agroecological research: conforming - or transforming the dominant agro-food regime? *Agroecol. Sustain. Food Syst.* 38, 1127–1155. doi: 10.1080/21683565.2014.951459

Maughan, C., and Amos, D. (2022). *Weeds as Bioindicators: A Farmer's Field Guide*. Pearl Moss Press. Available online at: https://www.agroecologynow.com/wp-content/uploads/2022/02/Bioindicators-Field-Guide-A4-PDF-version.pdf (accessed July 03, 2023).

Maughan, C., Anderson, C., and Kneafsey, M. (2020). A five-point framework for reading for social justice: a case study of food policy discourse in the context of Brexit Britain. *J. Agricult. Food Sys. Commun. Develop.* 3, 1–20. doi: 10.5304/jafscd.2020.093.024

McCune, N., and Sánchez, M. (2019). Teaching the territory: agroecological pedagogy and popular movements. *Agricult. Human Values* 36, 595–610. doi: 10.1007/s10460-018-9853-9

Moeller, N., and CIDSE (2020). Finance for Agroecology: More than Just a Dream? An Assessment of European and International Institutions Contributions to Food System Transformation. *CIDSE*. Available online at: https://www.cidse.org/wp-content/uploads/2020/09/AE-Finance-background-paper-final.pdf (accessed July 03, 2023).

Montenegro De Wit, M., and Iles, A. (2016). Toward thick legitimacy: Creating a web of legitimacy for agroecology. *Elementa: Sci. Anthropocene* 4, 000115. doi: 10.12952/journal.elementa.000115

Mortan, M., Ratiu, P., Veres, V., and Baciu, L. (2016). A global analysis of agricultural labor force. *Manag. Challen. Contemp. Soc. Proceed.* 9, 57.

Njukwe, K. E. (2015). *Farmer Participation in Research-for-Development to Enhance Cassava Production in Cameroon*. Kyoto: Shoukadoh Book Sellers.

Pansera, M., and Owen, R. (2018). *Innovation and Development: The Politics at the Bottom of the Pyramid*. John Wiley and Sons. doi: 10.1002/9781119453604

Pimbert, M. P. (2018). "Democratizing knowledge and ways of knowing for food sovereignty, agroecology and biocultural diversity," in *Food Sovereignty, Agroecology and Biocultural Diversity. Constructing and Contesting Knowledge*, ed M. P. Pimbert (Routledge, Taylor & Francis Group.), pp. 259–321. doi: 10.4324/9781315666396-8

Pimbert, M. P., Moeller, N. I., Singh, J., and Anderson, C. R. (2021). "Agroecology," in *Oxford Research Encyclopedia of Anthropology*. Oxford University Press. doi: 10.1093/acrefore/9780190854584.013.298

Richardson, M., Coe, R., Descheemaeker, K., Haussmann, B., Wellard, K., Moore, M. Y, et al. (2021). Farmer research networks in principle and practice. *In. J. Agricult. Sustain.* 3, 1–18. doi: 10.1080/14735903.2021.1930954

Roschinsky, R., Simon, S., Choudhury, P. R., Baroi, A., Malla, M., Costa, S. G., et al. (2016). "Facilitating climate change adaptation on smallholder farms through farmers' collective led on-farm adaptive research: The SAF-BIN Project," in *Implementing Climate Change Adaptation in Cities and Communities* (Springer), pp. 205–219. doi: 10.1007/978-3-319-28591-7_11

Rosset, P. (2013). *Agroecological Revolution: The Farmer-to-Farmer Movement of the ANAP in Cuba*. Available online at: https://www.academia.edu/5106454/AGROECOLOGICAL_REVOLUTION_The_Farmer-to-Farmer_Movement_of_the_ANAP_in_Cuba (accessed July 03, 2023).

Rosset, P., Val, V., Barbosa, L. P., and McCune, N. (2019). Agroecology and La Via Campesina II. Peasant agroecology schools and the formation of a sociohistorical and political subject. *Agroecol. Sustain. Food Syst.* 1–20. doi: 10.1080/21683565.2019.1617222

Salembier, C., Segrestin, B., Sinoir, N., Templier, J., Weil, B., Meynard, J-. M., et al. (2020). Design of equipment for agroecology: coupled innovation processes led by farmer-designers. *Agricult. Syst.* 183, 102856. doi: 10.1016/j.agsy.2020.102856

Sontakki, B., and S. P, S. (2017). "Farmer innovation system: Repositioning the way we look at farmer innovations," in *Agriculture Under Climate Change* (Allied Publishers Pvt. Ltd), 383–391.

Stone, G. D. (2022). *The Agricultural Dilemma: How Not to Feed The World* (First edition). London: Routledge. doi: 10.4324/9781003286257

Taylor, B., and Van Grieken, M. (2015). Local institutions and farmer participation in agri-environmental schemes. *J. Rural Stud.* 37, 10–19. doi: 10.1016/j.jrurstud.2014.11.011

Timsina, K. P., Gairhe, S., ThapaMagar, D., Ghimire, Y. N., Gauchan, D., and Padhyoti, Y. (2016). *Effectiveness of on Farm Research: Evidence of Wheat Research in Nepal*. Lalitpur, Nepal: Government of Nepal, Nepal Agricultural Research Council (NARC), Socioeconomics and Agricultural Policy Research Division.

Tucci, C., Viscusi, G., and Gautschi, H. (2018). Translating science into business innovation: the case of open food and nutrition data hackathons. *Front. Nutri.* 5, 96. doi: 10.3389/fnut.2018.00096

Uphoff, N. (2019). *Improving International Irrigation Management with Farmer Participation: Getting the Process Right*. New York, NY: Routledge. doi: 10.4324/9780429043536

Utter, A., White, A., Méndez, V. E., and Morris, K. (2021). Co-creation of knowledge in agroecology. *Elementa: Sci. Anthropocene* 9, 00026. doi: 10.1525/elementa.2021.00026

Vanloqueren, G., and Baret, P. V. (2009). How agricultural research systems shape a technological regime that develops genetic engineering but locks out agroecological innovations. *Res. Policy* 38, 971–983. doi: 10.1016/j.respol.2009.02.008

Wezel, A., Bellon, S., Doré, T., Francis, C., Vallod, D., David, C., et al. (2009). Agroecology as a science, a movement and a practice. A review. *Agron. Sustain. Dev.* 29, 503–515. doi: 10.1051/agro/2009004

Wezel, A., and Soldat, V. (2009). A quantitative and qualitative historical analysis of the scientific discipline of agroecology. *Int. J. Agricult. Sustain.* 7, 3. doi: 10.3763/ijas.2009.0400

Wittman, H., James, D., and Mehrabi, Z. (2020). Advancing food sovereignty through farmer-driven digital agroecology. *Int. J. Agricul. Natural Res.* 47, 235–248. doi: 10.7764/ijanr.v47i3.2299