

**REVIEW**

# Co-creation of knowledge in agroecology

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The co-creation of knowledge is gaining recognition and use within the science, practice, and movement of agroecology. Knowledge co-creation fosters participatory learning and development, which differs from passive knowledge sharing. This approach can bridge the real and perceived gaps across diverse forms of knowledge, including what is often distinguished as farmers' traditional, Indigenous, tacit, or local knowledge and experts' scientific, western, or generalizable knowledge. Formal academic documentation of processes and outcomes related to knowledge co-creation is limited; therefore, we bring in examples of published research, drawing from fields of agroecology, participatory action research, and science and technology studies, along with a firsthand farmer perspective on co-creation. Combined, these frameworks offer insight into the potential benefits of knowledge co-creation in agroecology. Many of these challenges, such as navigating power dynamics, may be addressed through mindful research and community practices, including strong communication and transparent expectations and goals. Co-creation processes have traditionally and continually taken place between farmers and throughout communities without academic acknowledgment and/or interpretation of such. We reinstate the invaluable role of farmer-centered inquiry, understanding, and application, which offer benefits to individual farmers and their extended communities of practice and research, in addition to holding spiritual and cultural significance. The co-creation of knowledge in agroecology presents a compelling, adaptive approach and outcome for the increasingly complex challenges facing farmers and the agrifood system.

**Keywords:** Agroecology, Knowledge co-creation, Knowledge systems, Participatory action research

## 1. Introduction

It is becoming increasingly widely accepted among researchers, activists, and farmers that more applicable and sustainable outcomes are achieved when agricultural knowledge is co-created rather than transferred through top-down mechanisms. The latter, more hierarchical knowledge structures have historically been dominant within industrial agricultural research and extension, while co-creation has progressively gained recognition within agroecology (Warner, 2008; Cuéllar-Padilla and Calle-Collado, 2011). Scholarship on sustainable agriculture and agroecology repeatedly acknowledges and looks to Indigenous and local knowledge systems for valuable contributions to address system challenges (Carolan, 2006; Warner, 2006; Vandermeer and Perfecto, 2013; Méndez et al., 2016; Méndez et al., 2017; Heleba et al., 2016). Agroecologists have long recognized that incorporating the localized expertise and knowledge of farmers is central to transforming food systems that are seeking to be more socially just and ecologically sound (Cuéllar-Padilla and Calle-Collado, 2011). When engaging in co-creation of knowledge, farmers are identified across

a variety of contexts as innovators who inspire and lead bottom-up transitions within their communities (Chambers and Ghildyal, 1985; Cross and Ampt, 2016; Heleba et al., 2016). This is the basis of more inclusive research approaches such as participatory action research (PAR; Kindon et al., 2007).

The terms and approaches within knowledge co-creation are not well defined and are often misused. In this article, we define the co-creation of knowledge as a collaborative process involving 2 or more actors, who are intentionally integrating their knowledge and learning, resulting in the development of insights and solutions that would not otherwise be reached independently. This is different from the passive merging, incorporating, and/or exchanging of different knowledges, ranging from scientific data to cultural understanding. As an approach, knowledge co-creation can serve as an effective strategy to link diverse types of knowledge, including that of farmers and scientific researchers. This exchange of knowledge between actors can result in the creation of novel knowledge, but too commonly in the history of academic research, local knowledge and insight has been appropriated or co-opted by academics and called "new." We challenge the broad notion of "new knowledge" and the related processes of "discovery" of existing wisdom and promote reverence, consent, and acknowledgment for the traditional knowledge that much "new" knowledge

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repeats and/or builds upon. Although not always the case, in this review, we use “knowledge co-creation” interchangeably with “knowledge co-production.” We also regard “knowledge” as a broad term inclusive of data, information, and wisdom. However, it should be recognized that many distinctions can be made among forms of understanding based on factors such as knowledge acquisition processes and formal contextualization (Jasanoff, 2004).

Throughout the world, farmers are constantly engaged in informal field and market research to improve agricultural methods and outcomes. This is research, although farmers are unlikely to refer to it as such. As described by Milgroom et al. (2016), “farmers continuously build situation-specific knowledge that allows them to develop under unpredictable and changing circumstances” (p. 6). At the farm level, knowledge creation usually involves a farmer identifying a question or challenge on or related to the farm; this is often followed by an attempt to resolve it through observation or trying something different and then drawing conclusions about the process and results. This process may be catalyzed by curiosity, necessity, or an accidental discovery rather than the explicit intent to understand and explain mechanisms or processes. In addition to independent research, farmers may engage in collaborative inquiry, often farmer-to-farmer or farmer-led, which could also be considered knowledge co-creation. Many nonfarmers, including academics, extension professionals, and development practitioners, highly value the knowledge that results from this type of on-the-ground experiential research by farmers.

In processes involving academic researchers, co-creation of knowledge offers a range of benefits compared to top-down knowledge transfer, especially in circumstances when there is a desired action from farmers (e.g., adoption of a sustainable practice). Research encouraging a process of collective inquiry can offer farmers and collaborators the advantage of increased salience, legitimacy, credibility, and familiarity, along with more informed decision-making and greater understanding of complexities (Cash et al., 2006; Warner, 2006). In turn, academics and extension professionals benefit from improved framing, translation, and rates of adoption and use for desired outcomes, such as that related to sustainable agriculture (Cash et al., 2006; Robinson, 2013; Meadow et al., 2015). However, the benefits associated with co-created knowledge depend on a range of factors, including the positionality, intent, and approach of actors. Additionally, as researcher-practitioners of agroecology, we value co-creation processes in agroecology as preferable to top-down knowledge transfer or extractive research processes. Co-creation is more participatory, inclusive, and equitable to diverse actors, along with improved outcomes in adoption of and commitment to agroecological practices.

While some recent literature describes the elements of successful knowledge co-creation and the co-benefits resulting from engagement, the actual process of co-creation remains less understood (Meadow et al., 2015). In this review, we aim to examine existing documentation

of and potential for the co-creation of knowledge in the field of agroecology. To overcome the limited literature base, we look at related approaches and fields of study. In doing so, we acknowledge the inherent limitations of drawing on perspectives from research publications, which often center on academic worldviews. We first outline relevant terms, followed by an overview of the interpersonal, intersectional, and transdisciplinary dimensions of knowledge co-creation. We also include insight and experiences on knowledge co-creation shared by a Vermont farmer to exemplify a practitioner perspective. We then discuss opportunities and challenges for knowledge co-creation within agroecological approaches, concluding with recommendations for moving forward.

## 2. Review of relevant terms

### 2.1. Agroecology

The definition of agroecology has continually evolved from its framing in the 1980s as the application of ecological science in sustainable agriculture to the more recent holistic conception of agroecology as a science, practice, and movement, as described by Gliessman (2018):

*Agroecology is the integration of research, education, action and change that brings sustainability to all parts of the food system: ecological, economic, and social. It's transdisciplinary in that it values all forms of knowledge and experience in food system change. It's participatory in that it requires the involvement of all stakeholders from the farm to the table and everyone in between. And it is action-oriented because it confronts the economic and political power structures of the current industrial food system with alternative social structures and policy action. The approach is grounded in ecological thinking where a holistic, systems-level understanding of food system sustainability is required. (p. 599)*

Toledo (2016) highlights the role of science in the tripartite model of agroecology, asserting that it is an “epistemological and methodological leap that generates new ways of doing science,” as well as recognizing it as a “politically and socially committed science” (p. 19). For example, agroecological scientists in Latin America are embracing the “epistemology of the South” and the tangential processes of the “decolonisation of the mind” through critique of cultural bias originating from European perspectives. Thus, the agro-industrial food system and its underlying pillars of “progress, development, and competition” are challenged in considering them with a different epistemological lens (p. 20).

Since the inception of agroecology research, the integration of scientific knowledge with other forms of knowledge has often helped guide the design and management of sustainable agroecosystems (Gliessman et al., 1981). As agroecology evolves and expands its focus to include

agrifood systems, researchers and practitioners are taking greater interest in critically assessing how a framework can be established to encourage and document knowledge co-creation processes in agroecology. Some agroecological perspectives pursue a transdisciplinary approach that explicitly integrates different types of knowledge systems to seek solutions to key issues in the agrifood system (Méndez et al., 2016). Parallel to that, social rural movements and peasant rural movements have embraced agroecology as a preferred approach for farmers to implement in the field, and these organized movements advocate for governments and international institutions to also support this approach (Altieri, 1998; Rosset and Martinez-Torres, 2012). Agroecology includes the implicit valuing of farmer knowledge and participation, but what it really means to co-create scientific knowledge and local knowledge together is distinct, and only recently has it been documented or discussed more in-depth.

## 2.2. Diverse knowledge systems

Knowledge systems may be defined as “a multiplicity of actors and networks through which certain kinds of technical and social information are communicated and negotiated” (Thompson and Scoones, 1994, p. 58). Thompson and Scoones (1994) frame knowledge and knowledge systems as social processes, where information is communicated and negotiated, emerging as a product of interaction and dialogue among various actors with different, sometimes competing, interests and knowledge gaps. This perspective was conceptualized by scholars and international development professionals working with resource-poor farmers in the 1980s and early-1990s (e.g., Chambers and Ghildyal, 1985; Chambers and Jiggins, 1987; Scoones and Thompson, 1994; Van Veldhuizen et al., 1997). This approach to knowledge systems is tied to a shift away from top-down transfer of technology to a bottom-up participatory approach that can better meet the complex and socially–politically situated needs of farmers.

Knowledge systems are often simplified into the binary classification of (1) traditional/Indigenous/tacit and (2) scientific/western/generalizable, referred to as “traditional knowledge” and “scientific knowledge,” respectively, in subsequent discussion. However, scholars such as Agrawal (1995) point out that this dichotomy rests on limited and unreliable characteristics and instead encourage focus on the *similarities* between knowledge systems. Berkes (2009) also emphasizes investment in dialogue and partnerships while embracing the integrity of distinct epistemologies and world views to honor cultural context, especially within traditional knowledge. Along this vein, we embrace the prevailing dichotomy as a compelling and thoughtful opportunity for collaboration to bridge real and perceived gaps among different knowledge systems through the process of co-creation.

Traditional knowledge has been studied by scientists, including agroecologists. However, this has not been frequently done within a knowledge co-creation framework. In other words, even when these various types of knowledge have been identified and valued, they are usually not merged coalesced through a process of horizontal

participation and development. Historically, academics have primarily focused on understanding and explaining the mechanisms by which some of this knowledge expresses itself, and in promoting the advancement of these practices, rather than the co-creation aspect. For instance, there is great interest in the ecological and cultural content of the traditional 3 sisters cropping system, which combines maize, beans, and squash in the Americas (e.g., Demchik and Demchik, 2011; Postma and Lynch, 2012). This is similar to the process of scientists gleaning information from Indigenous cultures and traditional ecological knowledge to inform climate change studies, as discussed by Berkes (2009). This selective focus on specific content that may complement or align with scientific findings may overlook the underlying experience and process inherent to much traditional knowledge. Scholars, such as Nanjunda (2008) and Agrawal (1995), highlight the irony in the efforts to valorize tacit knowledge by first seeking scientific validation of it, thus continuing to perpetuate a dichotomy that prioritizes scientific knowledge. The co-creation of knowledge, particularly applied within an agroecological framework, may set the foundation for future research that not only looks to traditional knowledge but recognizes its intrinsic value independently and as critical depth within co-creation.

In Berkes' (2009) discussion of Indigenous knowledge and environmental change research, he states:

*Indigenous knowledge evolves all the time and involves constant learning-by-doing, experimenting and knowledge-building (Berkes, 2008); I would speculate that, on the whole, it is probably not more conservative than Western science. I would further speculate that many Indigenous knowledge holders are open to a dialogue and partnership with science—about as much as scientists are. (p. 154)*

Berkes promotes sensitivity toward different ways of knowing, especially within our past and future educational system, and recognizes varying interests of different actors for engaging in dialogue, including from those who have suffered historically from colonialism. Similarly, discussing co-creation, Gliessman (2017) posits:

*New knowledge is constantly being created in our food systems. Farmers are constantly observing and testing new practices, seeds, tools, and relationships. Agroecology researchers are constantly testing and experimenting in order to understand the ecological foundations of food system function and management. Social movements are constantly listening and integrating the knowledge, needs, and points of view of the people at the frontlines of the struggle for food system equity, fairness, and food justice. When these three forms of knowledge are linked (something academics call transdisciplinarity), new knowledge is created. And change occurs. (p. 1)*

The diversity inherent to the co-creation of knowledge may be navigated in different ways. Ayala-Orozco et al. (2018) explore it in context to place-based multi-stakeholder collaboration (MSC), defined as “the interactive process in which actors with diverse points of view work together, implementing collective action, and sharing risks, resources, and responsibilities” (p. 2). Through participatory workshops, the study examined 38 sustainability projects, including challenges across varying ecological, social, and political contexts. The top obstacles emerged as divergent visions and interests, inadequate planning and project management, inadequate organization among stakeholders, problems of communication and lack of information, and structural conditions. The most common reported challenge, divergent visions and interests, was related to factors such as “unbalanced stakeholder participation” and “mistrust between collaborators” (p. 5). This divergence was identified as particularly challenging in the beginning of MSC process defining common goals and agendas and may be mitigated through approaches such as popular education and PAR.

The notion of co-creation may sometimes be perceived as distinct forms of knowledge always being merged or integrated. However, the decolonial perspective acknowledges that some knowledge, especially that from different cultures, may be related and therefore interrelated but not merged and integrated because they are by nature incommensurable (Blaser and De la Cadena, 2017). Blaser and De la Cadena (2017) put forth the term “uncommons”: the aspects that cannot be merged or integrated. By emphasizing and bringing focus to the uncommon aspects of knowledges that are being integrated, a unique value is put on that which is left behind and what diverges. Through highlighting the uncommon, the translation of knowledge that undergirds process of co-production comes closer to “living up to its democratic and egalitarian promise” (Blaser and De la Cadena, 2017). Blaser and De la Cadena (2017) discuss this using the “ecology of practices” framework put forth by Stengers (2005):

*The practices that interest us are constituted by their own positive divergence as they symbiotically come together—like in an ecological system—while also remaining distinct: what brings them together is an interest in common that is not the same interest. The point of uncommoning, then, is not to preclude the possibility of commoning but rather, whenever possible, to seek ways to base the latter on the more solid grounds of recognised productive divergences. (p. 191)*

The notions of uncommoning and “dialogue of knowledges” point to the way knowledge systems can interact without combining and hence evading subsuming or co-optation of any knowledge system by another. This can lead to positive, neutral, or negative engagements among knowledge systems.

Again, the term “new knowledge” could be debated on questions of “new” versus “old” knowledge and when an understanding of agroecological processes becomes “knowledge.” There is unique value in co-creation as a process bringing together diverse knowledge systems and serving as a catalyst for the advancement of the science, practice, and movement of agroecology.

### 3. Interpersonal, intersectional, and transdisciplinary dimensions of knowledge co-creation

#### 3.1. Factors shaping co-creation processes and outcomes

A variety of factors have been linked to the general processes and outcomes of knowledge co-creation. Jasanoff (2004) frames co-production as an idiom with fluxing intersections among culture, sociopolitical/organizational frameworks, knowledge, and invention. It is distinct from “laws of nature” as it “does not seek to foreclose competing explanations by laying claim to one dominant and all-powerful truth” (Jasanoff, 2004, p. 43). The work of Jasanoff and other contributors highlights the range of applications of co-creation, from highly introspective and localized projects to more abstract renderings adapted to globalization. This view of co-production of knowledge differs from more recent proposals by some in the climate change research community, which can be seen more as a convening of stakeholders in order to develop applicable responses to climate change (Lemos et al, 2018).

In the context of scientific research for sustainable development, Cash et al. (2003) identify communication, translation, and mediation as the 3 major functions of knowledge systems. They also identify credibility, salience, and knowledge as factors influencing scientific information’s impact on social responses to public issues. In other words, when individuals receive information from a trusted source, there is an increased likelihood that they will mobilize toward a desired action. Relatedly, Berkes (2009) cites the basis of knowledge co-production to include willingness and openness, humility, development of working relationships, trust-building, and respect for areas that should not be researched.

Carolan (2006) explores the co-creation of knowledge in agroecology through a sociological inquiry into the co-production of knowledge in the sustainable agriculture movement in the United States. The themes of co-creation that emerge include (1) variable levels of engagement and decision-making roles that occur both organically and intentionally; (2) shifting power dynamics from top-down information delivery to co-produced knowledge, giving farmers voice in the development and application of research; and (3) the meaningful interaction of different actors to co-produce new knowledge that is valuable to all actors (e.g., farmers, researchers and nonresearchers, and academics and nonacademics).

Similarly, research by White and Utter (2021) explores factors, as identified by agricultural outreach professionals, which either encourage or hinder the co-creation of knowledge with farmers. We find that the critical elements of successful co-creation of knowledge

include listening and empathy, mutual respect, flexibility, follow-through, and trust and relationship building. This emphasizes the importance of mindful interactions and processes that are transparent and equitably negotiated. Mismatched terminology between farmers and advisors or researchers and incompatible expectations for participation/outcomes have been identified as barriers to the co-creation of knowledge (Briley et al., 2015). To advance the conceptualization and practice of agroecological knowledge co-creation, it is important to promote clarity while considering the direct and indirect impacts of potential outcomes on actors participating in the knowledge co-creation as well as community members and others who may be affected.

In the context of climate change adaptation, Hegger et al. (2012) put forth a framework with 7 conditions for analyzing successful joint knowledge production. Each relates neutrally or positively to credibility, salience, and/or legitimacy:

1. “Broadest possible actor coalition within limits present
2. Shared understanding on goals and problem definitions
3. Recognition of stakeholder perspectives
4. Organized reflection on division of tasks by participating actors
5. Role of researchers and their knowledge is clear
6. Presence of innovations in reward structures
7. Presence of specific resources such as boundary objects, facilities, organizational forms and competences” (Hegger et al., 2012, p. 61).

More recently, Hegger et al. (2014) suggested that joint knowledge production projects can be improved through encouraging reflection throughout the project, creating reward structures for actors that develop new initiatives and creative ideas, and integrating opportunity to make and learn from mistakes.

Bello Cartagena (2019) expands on Hegger’s process-oriented frameworks to consider outcomes and impacts specific to knowledge co-creation and agroecology through a systematic literature review. Within this revised structure, success is defined as “when agro-ecological farming behavior is positively influenced towards the (re) design of agroecosystems based on ecological principles” (Bello Cartagena, p. 21). In Bello Cartagena’s study on knowledge co-creation in context to agroecology, only 6% of the 69 empirical samples were identified as having successful impacts. The similarities among these were the application of on-farm PAR, the co-design of content and process, and a sense of belonging/attachment. A small subsampling was evaluated for the potential correlation of successful outcomes and 3 theoretical indicators: credibility, salience, and legitimacy. Findings indicated that successful outcomes of co-creation

processes were likely to be strong in the 3 indicators. However, unsuccessful outcomes were not necessarily correlated with lack of indicators but potentially by the presence of external factors that superseded the indicators. Examples of these external factors included resource limitations, power imbalances, financial/regulatory obstacles, or for farmers to be already using/evaluating a different alternative farming approach. This research validates the gap between knowledge co-creation and the implementation of agroecological practices. To further develop co-creation as a successful transformational process, strategic inclusion of agroecological principles, which have local relevance, is recommended as part of researcher–farmer co-creation efforts.

These aforementioned themes are foundational within PAR scholarship, and other analog expressions of knowledge co-creation, including science and technology studies where horizontal knowledge co-creation is seen as falling into the Mode 2 science-policy model (e.g., Kirchoff et al., 2013). Mode 2 does not prioritize “scientific knowledge” over “societal knowledge” or “experiential expertise,” and knowledge is considered with regard to persons and contexts; thus, “it is not always possible to separate opinions, ideas and facts from one another” (Reger and Bunders, 2009, p. 57). Modes 1 and 2 embody the binary distinction between a top-down transfer of knowledge (Mode 1) and transdisciplinary horizontal co-creation of knowledge (Mode 2).

### 3.2. Potential actors

Within agroecology, the co-creation of knowledge may occur among various actors, including farmers, community members, individuals from governmental and non-governmental entities, and researchers. The main co-creation relationships that we focus on in this article are researcher–farmer and farmer-to-farmer. In all cases, we recognize the engagement of farmers and other actors is essential within the co-creation of knowledge that seeks to advance agroecological systems. A farmer-centered approach is fundamental in achieving sovereignty in the agrifood system. Additionally, the intimate, place-based wisdom of farmers is unmatched in many regards to the information developed exclusively within the academic community. Although we encourage prioritizing and honoring farmer participation in co-creation, we also caution against the fetishization or tokenization of farmers as partners through pathways such as “nominal participation” as discussed by White (1996).

As noted by Jasanoff (2004), a key piece of co-production is related to cultural transformation and the recognition of “knowledge users” as also being “knowledge authors,” and of “extended peer communities” including non-scientific user or stakeholder groups (p. 104). One of the more difficult aspects of knowledge co-creation is addressing the needs, interests, motivations, and aspirations of the different actors participating in the co-creation process. In the following section, we explore potential motivations for farmer engagement in co-creation.

### 3.3. Motivations for farmer engagement

Farmers have a variety of potential motivations driving them to seek academic and technical experts to support them in problem solving (e.g., Matata et al., 2013). For example, Dogliotti et al. (2014) discuss “co-innovation” in context to 14 family farms in Uruguay and a multiyear project involving farmers, technical advisers, and scientists. Innovations were developed and aimed at redesigning farms for improved sustainability for farmer livelihoods and the environment. A key finding of the project emerged around the role of extension service agents in long-term planning. Farmers reported a “need to change the role of extension service agents and technical advisers from mere consultants on operational and tactical decisions to supporters of the process of planning and evaluations of farm systems” (p. 85). This highlights the value of actors being open to shifting roles and contributions for effective co-innovation, and subsequently, knowledge co-creation. These contributory and reciprocal processes are dependent on the valuation of diverse knowledge and are essential for the horizontal participation that is central to co-creation. As fundamental actors within co-creation, farmers’ perspectives and motivations for engaging in co-creation processes are very important. However, there is limited documentation and analysis of farmers’ opinions and motivations for participating in these processes.

In the co-creation process, there may be inherent privilege and power dynamics related to societal and individual differences in gender, education, social class, ethnicity, and so on (e.g., Pohl et al., 2010). Throughout the process, actors should continually work toward transparency and equity by engaging in honest dialogue about the expectations and benefits of the co-creation process. It can be easy for academics and other agricultural outreach professionals to believe that a process of co-creation for agroecology will be beneficial to all. However, this belief can be limited to the perspective of professionals whose motivations and objectives may be shaped by academic priorities. Alternatively, farmers may experience different pressures, such as financial strain, food security stress, and a calendar built around weather, the growing season, and markets, rather than academic or fiscal year calendars. In an agroecology that seeks to serve farmers, their families, organizations, and communities, we must continue to ask the questions: What benefits and outcomes do farmers seek from an agroecological co-creation process? How can our different perspectives and access to different networks and resources be maximized, and result in mutual benefits? (Méndez et al., 2017). To begin to explore these questions, we follow with a section featuring the insight of a farmer who has firsthand experience working with researchers and other partners in processes of knowledge co-creation.

#### 3.3.1. A Vermont farmer’s perspective on knowledge co-creation

In this section, we discuss observations shared by John Hayden, a Vermont-based farmer with decades of experience in diversified farming and a frequent participant in both farmer-led research and PAR. The insights outlined

below were drawn from a discussion between John and the lead author of this article on May 24, 2018. Their conversation was recorded through handwritten notes, and the resulting data were approved by the farmer for inclusion in this article.

Although John did not explicitly define it as “co-creation,” he differentiated between the informal process of independent on-farm experimentation and intentional partnerships structured to create new knowledge. Overall, he identified the main goal of independent knowledge development as answering a question important to that farm and farmer and to enrich their personal understanding of the farm system. The information may later be shared farmer-to-farmer or within broader agricultural networks, but this sharing was not fundamental to the success of the initial process. Furthermore, since the individualized knowledge generated through this process may not be relevant to other farms, its applicability to other farms may be limited even if it were shared.

Alternatively, within the farmer-initiated approach of the co-creation of knowledge, John stated that he would seek partnerships with individuals or organizations if he felt that the overall processes and outcomes of sustainable agriculture, in general, would improve with this collaboration. The main benefits he associated with such partnerships included, in no particular order: (1) increased topical expertise, (2) labor support for implementation, and (3) financial assistance for experimentation. Farmers may also consider engaging in a co-creation research process even when they do not expect a direct benefit. For example, they may have a disposition to help their collaborator. John elaborated on this:

*There is another type of co-creation of knowledge where the farmer empathizes with the need of a grad student to collect data and cooperates altruistically by offering land, time or resources as assistance. . . . I have done this before, even though I didn't see any immediate benefit to me from the knowledge gained. Sometimes farmers are just being nice, or in situations of unequal power, giving in to the person with higher status who requests to collaborate.*

John also expressed that he did not place a high value on information sharing through academic publications but recognized that it was often important to university-affiliated collaborators. For those actors in co-creation who identify formalized data or publications as a priority, it is important to also consider potential gains for farmers. Although publications may be treated as “currency” within the research/academic community, farmer partners will likely emphasize the potential individual benefits, such as generating knowledge relevant to their farm setting or other tangible benefits tied to their livelihood. In the short term, this could be a stipend to offset the financial or time cost of engaging in a co-creation process. Examples of costs to farmers for participating could include reduced land for production (e.g., if used for research trials) and decreased farmer time to devote to other tasks. This may be especially relevant in areas where the growing

season is relatively short or in situations where the co-creation process limits a farmer's ability to generate their respective agricultural currency (crops, livestock, agritourism, etc.) for subsistence or the marketplace. However, these potential discrepancies and challenges should be expected to differ across actors and should be negotiated in a transparent way on a case-by-case basis.

### 3.4. Navigating power dynamics in co-creation relationships

As mentioned above, farmer participation is a critical component of the co-creation of knowledge in agroecology and requires mindful navigation of power dynamics. Ideally, the co-creation of knowledge in agroecology takes place across a horizontal framework, as opposed to a top-down structure with few benefits to those at the bottom (Méndez et al., 2016). Participants are encouraged to be mindful of navigating the participation process, which can be extremely complex; knowledge and power are intimately related. Jasanoff (2004) states:

*It [co-production] provides a constant reminder that, not only does knowledge constitute power, but equally power frames and organizes knowledge; hence, wherever power originates or is concentrated, one should also look for its expression through knowledge. . . . co-production sees the very taken-for-grantedness of entrenched power structures as a spur to further inquiry. (p. 280)*

White (1996, p. 6) cautions, "While participation has the potential to challenge patterns of dominance, it may also be the means through which existing power relations are entrenched and reproduced." Participation can represent different interests and functions and can take different forms depending on the level of participation. White (1996) classifies 4 types of participation, with emphasis on their implications for "actors at the top" (with power) versus those "at the grassroots" (with relatively less power):

1. Nominal participation: used by actors with greater power to legitimize outcomes through cultivating feelings of inclusion among those with less power, though it is more of a display than a process generating mutually negotiated outcomes;
2. Instrumental participation: the incorporation of community members' skills/knowledge with focus on efficiency to achieve a means to an end;
3. Representative participation: includes community members throughout the decision-making and ongoing implementation process, which offers an opportunity for leverage from the grassroots; and

4. Transformative participation: a process that leverages solidarity from more powerful actors and results in empowerment of less powerful actors; this has the potential to achieve the most significant alteration of dominant power structures.

Ideally, the co-creation process fosters transformative participation, where actors across various positions of power and privilege are committed to transparently and cooperatively working together. One means to achieve transformative participation and increase the likelihood of farmers' needs being met is through the use of PAR, discussed in detail in the following section. Generally, the objectives of this type of knowledge co-creation are for researchers and nonresearchers to engage in inquiry together, in order to address an issue of interest to all partners (Méndez et al., 2017). There is relatively little documented information of the intricacies of knowledge and internal power dynamics of farmer-initiated or farmer-led co-creation. Therefore, we explore some foundational examples in the following section on the opportunities for knowledge co-creation.

In many research relationships, the knowledge "producer" may be an individual or entity in a position of real or perceived power (e.g., academic researcher) relative to the knowledge user (e.g., farmer). These roles are less binary and more horizontally adaptive in the co-creation of knowledge; however, it is still useful to acknowledge the broad democratic dimensions and power dynamics of relationships between knowledge producers and users, which can influence the character, usability, and form of outcomes from the co-creation of the knowledge process. Delgado (2008) examines the expert-lay divide in the context of the Landless Peoples Movement/Movement Set Terra in Latin America. She advocates for "interactional reflexivity," which "entails a reflection on how expertise is framed and the implications of that framing for participation" (p. 560). Delgado calls on experts to go beyond vetting expertise and take responsibility for opening spaces that allow for dialogue and action.

There has also been increasing attention given to the processes and relevancy of results, with even greater scrutiny from those outside of the academy of research projects initiated by researchers within academia. Olesen and Nordentoft (2013) emphasize that researchers must build dialogue-oriented facilitation skills to better navigate the inherent power-laden responsibility of researcher-facilitator in these spaces. In some situations, actors outside of academia have a deep distrust of the motivations of scientific experts, understanding fully that research can be extractive and of no real value to them. This in turn leads to complex power dynamics that usually need to be overcome for the process to be beneficial to all participants (Méndez et al., 2017). These dynamics are further discussed in the following section. This has sometimes been overcome by relationship building and social capital. Dilling and Lemos (2011) identify iterative exchanges between knowledge users and producers as critical to

creating information that will be usable. These repeated interactions between information users and information producers build trust and enhance sensitivity to the decision-making context and the perceived utility of science (Dilling and Lemos, 2011). This further reveals that power dynamics not only influence the process and interpersonal dimensions of co-creation but also shape the outcomes and implementation of the resulting knowledge.

Several approaches exemplify the potential of transdisciplinary collaboration that challenge Mode 1 values, including hierarchical power structures prioritizing scientific researchers as authoritative producers of knowledge. These approaches may occur simultaneously with, or supplement, co-creation and include PAR, farmer-to-farmer, and farmer-led approaches. The lines between these are not always clear since they frequently overlap. Nevertheless, it is useful to attempt to delineate between them and their related actors, objectives, and outcomes to understand nuances in the path toward knowledge co-creation.

#### 4. Opportunities for encouraging knowledge co-creation in agroecological approaches

##### 4.1. PAR

PAR is engaged research with the explicit goals of building collaboration between researchers and participants, generating benefits for all involved, and allowing critical reflection (McIntyre, 2008). In this type of applied, action-oriented research, the process includes observation and reflection that can inform community action and potentially influence policy. PAR and other collaborative “actor-oriented” processes have sought to replace the top-down, extractive model of research with an approach that benefits the communities involved. Participatory approaches prioritize democratic processes and community engagement to effect change around local concerns (Kendon et al., 2007). According to Méndez et al. (2017), PAR usually takes the form of cyclical processes that have different iterative stages, including reflection (developing a relationship), reflection, research, and action. Ideally, the research design, objectives, data collection, and analysis are generated through a participatory and transparent process, with all partners being actively involved. PAR seeks to integrate the knowledge of nonresearch partners as part of the research process, and successful examples of PAR are generally able to integrate these different forms of knowledge to find solutions to issues and generate new and useful knowledge.

Although PAR originated in the social sciences, the application of PAR has become more commonly applied in natural resource fields (Castellanet and Jordan, 2002), and PAR is widely viewed as a valid and important research approach in the social and environmental sciences, as well as rural development (Kendon et al., 2007; Geilfus, 2008). Since agroecology promotes the blending of traditional knowledge and scientific knowledge, PAR is a natural fit within the field and practice of agroecology (Altieri, 1999). Combined, PAR and agroecology provide a means for smallholder farmers with localized knowledge to connect with practitioners versed in broad applications of

formalized scientific inquiry. One of the strengths of PAR is that it brings flexibility and context specificity to agroecological research. These strengths can also present a challenge in that the research results may be so localized that they cannot be broadly applied elsewhere.

Méndez et al. (2017) examined PAR within agroecology through case studies with smallholder coffee farmers in El Salvador, Mexico, and Nicaragua. These case studies are used to discuss the significance of the following PAR principles, which can be used to analyze processes in different contexts: (1) a shared belief in collective power/action/commitment to the participatory process, (2) the value of cultivating trust and accountability between partners, (3) the importance of approaching the process with humility and an openness to continual reflection, and (4) the importance of transparency and good communications. Méndez et al. (2017) also make other important observations about PAR, including the possibility that research processes that do not start as PAR may evolve into PAR over the course of the research, and that including multi-generation participants can help include farming family youth in the collaborative relationship, and ensure sustainability and continued evolution of the PAR process.

Given the parallels between PAR and the co-creation of new knowledge, co-creation processes may follow a similar pattern of developing into a collaborative process even if they were not explicitly defined as such at the outset. For example, Rachel Bezner Kerr’s work in southern Africa is participatory and involves information exchange, which in some cases leads to the co-created development of new knowledge, though it is not explicitly planned or labeled as such (e.g., Bezner Kerr et al., 2007a; Bezner Kerr et al., 2007b; Bezner Kerr et al., 2011; Snapp et al., 2013; Bezner Kerr, 2014; Bezner Kerr et al., 2019). For example, Bezner Kerr et al. (2019) draw on a 17-year collaboration in northern Malawi with smallholder farming households practicing agroecological methods. This long-term PAR process centers on dialogue, experimentation, and horizontal learning with attention to class and gender in relation to food sovereignty. This process features farmer experiences and farmer-to-farmer exchanges, such as through discussion groups, to ultimately identify intersections between marginalization and discrimination and advocate for social change essential to food sovereignty.

Considered by many, as foundational, the work of Freire (2017) and Fals-Borda and Rahman (1991) incorporates a strong political orientation to the PAR process. In both cases, PAR is proposed as a means to support individual and collective empowerment of oppressed populations, so they can better advocate for their interests. The political inclinations and actions of a PAR process can vary, but by addressing power dynamics and justice in favor of the oppressed, it is hard to distance it from at least some form of political engagement. PAR work in agroecology has increasingly embraced a political orientation, as the field engages more in what has been recently termed as “political agroecology” (Molina et al., 2019) and social justice, and an increasing number of agroecology scholar-activists become more involved in social movements (López-García et al., 2021).



As discussed above, PAR was established as a response to the prevailing methods of extractive, top-down research. PAR highlights the potential transformation in tangible and equitable outcomes through horizontal, transdisciplinary collaborations inclusive of different sets of expertise (Kindon et al., 2007). We highlight the fundamental elements of PAR in this discussion of knowledge co-creation because there is substantial overlap in these 2 approaches; co-creation may be considered entirely separately from PAR or as a component (process/outcome) within PAR. PAR is often initiated by researchers, and it is important to also examine processes that are initiated by other actors, including farmers. In the subsequent section, we discuss examples of farmer-initiated knowledge co-creation.

#### 4.2. Farmer-centered/led co-creation processes

PAR practices were developed in response to top-down knowledge transfer; farmer-to-farmer and farmer-led knowledge co-creation represent further progression away from top-down knowledge transfer and toward horizontal development and exchange of knowledge among farmers, as well as between farmers and other types of practitioners. These farmer-centered processes encourage knowledge co-creation that captures the interests and needs of farmers. This is important in terms of equity and also because farmers are key agents and critical actors in defining the interventions, resources, and new knowledge they need for sustainable livelihoods (Scoones and Thompson, 1994; Reij and Waters-Bayer, 2001). While researcher-led projects may offer the benefits of credibility and legitimacy, from the perspective of western science, farmer-led inquiry into agroecological research and development has the potential to result in greater salience and usability for end users. In contrast to researcher-led approaches, farmer-centered processes may not have an explicit and/or formalized scientific research component.

Both farmer-to-farmer and farmer-led knowledge co-creation are broadly distinguishable based on the types of actors participating in a process, along with the roles that they play. These roles may not be defined early on and often continuously evolve over the process. There may be various discrepancies in the “leadership role,” distinct from someone initiating/coordinating the process and/or facilitating. For instance, a question may originate from a farmer, yet the co-creation process may not be farmer-led. Although we discuss farmer-led and farmer-to-farmer knowledge co-creation separately in the sections below, there are also many examples of these overlapping. Specifically, there are many instances of farmer-to-farmer co-creation also being farmer-led, though lesser so vice versa. Below, are examples that embody both farmer-to-farmer and farmer-led processes.

##### 4.2.1. Farmer-to-farmer and farmer-led co-creation of knowledge

The Campesino a Campesino (CaC) movement originated in Mesoamerica (Holt-Gimenez, 2006) and has since spread to other areas as well (e.g., Rosset et al., 2011). The intention of the CaC is to “promote a culture of enquiry

and experimentation among smallholder farmers” (Hocdé et al., 2000, p. 26). This is achieved through volunteer farmer “promoters” leveraging their own experience as farmers to connect with other farmers and assist in facilitating independent farm experimentation, from the inception of an idea to the interpretation of results. These farmer-vetted results tied to specific techniques and/or technologies can then be disseminated throughout the agricultural community, often within exchanges designed to encourage farmer-to-farmer discourse to collectively explore the topic with a variety of perspectives. The impact of utilizing strategies such as CaC and that from the National Association of Small Farmers (ANAP) can be seen in Cuba. The agricultural community was able to persevere through a collapse of the socialist bloc, along with a stringent U.S. trade embargo. This was done by leveraging the knowledge and resilience of Cuban peasant farmers to engage with agroecological, low-input strategies, both in rural and urban areas. Toledo (2016, p. 19) reflects on the Cuban and Brazilian experiences:

*Being forced into self-reliance, people organised themselves in neighbourhoods, city quarters, and cities, and found a way out of the food crisis through agroecology. The conversion to agroecology was so successful that the government had no alternative but to support it. Similarly, the most important farmer movements of Brazil (among them, the Landless Farmers' Movement) are successfully addressing a serious social crisis (land grabbing) also by adopting agroecology as their main paradigm.*

Another example of farmer-to-farmer and farmer-led knowledge co-creation is La Via Campesina. This international peasant movement advocates for equity and food sovereignty for landless workers and other rural community members who have historically been marginalized, especially within the context of the prevailing neoliberalist agrifood system (Val et al., 2019). Through efforts led by Via Campesina, including the “Global Campaign for Agrarian Reform,” farmers have been able to collectively define and pursue equitable land reform, reflective of the needs and goals of different communities around the world. This represents a form of co-creation of knowledge which is distinct in that it does not focus on a set of on-farm practices for the improvement of livelihoods. Instead, the emphasis is on the development of diverse farmer-to-farmer communities of practice at both the local and global scale to shape and catalyze sociopolitical movements (Martínez-Torres and Rosset, 2014).

Farmer-to-farmer processes facilitate the exchange of information between practitioners. The Food and Agriculture Organization's Farmer Field School (FFS) methodology brings farmers together to learn about specific practices under guided facilitation using “discovery-based” learning principles. Merging outside scientific perspectives on agriculture with community insight provides an opportunity for science-based concepts to be trialed for their practical field application, ultimately resulting in the

co-creation of new knowledge (Almekinders et al., 2014). A systematic review of impacts of FFS promoting integrated pest management in low- and middle-income countries found FFS enhanced both intermediate outcomes (improved knowledge and reduced pesticide use) and final outcomes (13% increase in agricultural yields and 20% raise in income) for farmers (Waddington et al., 2014). Although these findings demonstrate the potential impact of FFS, there is no indication that neighboring farmers who do not directly participate in FFS benefit from the diffusion of knowledge. Additional concerns include scaling FFS beyond regional communities due to limitations in recruiting and training scale-appropriate facilitators. Finally, limited data are available on the impacts, especially longitudinally, of FFS programs on farmer livelihoods. Much of what shapes the aforementioned benefits, and challenges, of FFS relate to the inherently observation and experience-based style of learning, which focuses impact on participants.

An additional example, as featured in the *Farming Matters* special edition on the co-creation of knowledge, highlights the Network of Sustainable Agricultural Alternatives (RASA) in Mexico. The cooperative encompasses “100 families of farmers, peasants, Indigenous peoples, women, consumers, and advisors from twenty different municipalities” with a focus on “co-creation of knowledge, strengthening rural-urban linkages through fair trade, and conservation of agrobiodiversity through the milpa system” (Hernandez, 2016, p. 27). A critical piece of RASA is the adoption of farmers as trainers and advisors for other farmers and the hosting of collectively organized events to include agroecology-centered “experimentation, seed recovery, encounters, tours, and workshops” with some involving farmer collaboration with scientists. In bringing together traditional farming practices (including native seeds) and knowledge co-creation, many participating RASA farms have increased agrobiodiversity and subsequently have been able to “regain food sovereignty in the family, withstand the rural crisis driven by agroindustry, and to achieve autonomy in their production systems.” RASA farms with longer engagement in agroecology also had average incomes that were 40% higher than the nation’s average (Hernandez, 2016, p. 27).

#### 4.2.2. Farmer knowledge networks

Farmer networks in both developed and developing countries play an important role in generating and applying knowledge on issues relevant to the local community. These issues range from political challenges addressed through social movements (e.g., La Via Campesina) to farmer-led traditional agricultural practices demonstrating increased climate change resilience (e.g., Altieri et al., 2015) to identifying areas in need of greater attention from agricultural outreach professionals (e.g., Warner, 2008). Here, we present a few examples of how farmers have led knowledge co-creation networks in agroecology, recognizing that the knowledge systems of Indigenous communities and many smallholder farmers across the globe are typically neither systematically recorded, nor made accessible to researchers and agricultural advisors.

Among agroforestry networks in eastern Africa, researchers attribute the direction of their research to their participation in a collaborative process led by farmer groups, who oversee on-farm research and facilitate workshops (Matata et al., 2013). In this case, a farmer network, formally titled The Network of Farmer Groups in Tanzania (MVIWATA), identified practical issues that limited their capacity to expand agroforestry, such as land fallowing, seed availability, information, and labor. Collaborating with researchers and government agencies, the farmer network created spaces where information could be exchanged, shared broadly, and evaluated against the technical and socioeconomic barriers to adoption identified by local farmers. Researchers conducted a study on dissemination pathways for scaling up agroforestry and found farmer trainers to be the most effective agents in delivering information, far more than local extension and governmental agents. This example illuminates the relationship between the successful adoption of methods, such as agroforestry, and the collaboration between regional farmers and project partners (researchers and government agencies). In this case, the nonfarmer collaborators were able to address the knowledge and resource gaps identified by farmers throughout the process.

Sustainable agriculture networks in industrialized countries have filled similar roles in creating spaces for farmer defined research priorities. The U.S. Department of Agriculture Sustainable Agriculture Research & Education (SARE) farmer grants offer a unique framework in that they provide an opportunity for farmers to leverage government funding to design, implement, and report on a research project in partnership with a technical advisor (e.g., Cooperative Extension Agent). In addition to encouraging farmer leadership, the structure of SARE prioritizes work that is relevant across farms. The reporting structure of the grant allows for farmer-generated research findings to be accessed by other farmers. Although this may foster a unidirectional information transfer between farmers, the process of developing the information between participating farmer(s) and the technical advisor represents co-creation of knowledge which may be useful to the participating farmer as well as to other farmers.

There are also other scenarios in North America where farmer-led co-creation occurs. For example, organic producers in Iowa took the initiative to experiment and share knowledge among themselves to address facets of organic production that local technical experts were unable to answer (Carolan, 2006). Years later, state extension programs reached out to these growers to learn about agroecological management strategies they had developed, such as rotational grazing and using eggshells as liming agents. Through this information transfer, farmers reported that they learned about soil chemistry and biology during these subsequent exchanges.

Hassanein and Kloppenburg (1995) place the emergence of sustainable agriculture networks to co-create new knowledge about agroecological management strategies within social movement theory. In their well referenced study, rotational grazing communities in the United States established systems of knowledge exchange and co-

creation which defied the technical advice and hierarchical information structures of the land grant system and government farm policies. As described by a Wisconsin-based farmer, “networks are ahead of the university . . . by maybe a couple of years. Maybe even further.” (Hassanein and Kloppenburg, 1995, p. 735). This places farmers and their networks as leaders in the identification of innovative research questions, strategies, and outcomes.

Among all of these examples, when farmers led in the co-creation of agroecological knowledge, they employed facilitation skills and interactional expertise, which is the capacity to communicate and exchange knowledge between different epistemological perspectives. This is a critical skill on the part of both farmers and researchers who lead co-creation processes. Farmer knowledge about new agroecological management strategies has historically been exchanged, revised, refined, and vetted within agricultural knowledge networks. Within these horizontal spaces, knowledge between actors (farmers and in some cases, advisors and technical experts) is negotiated and socially recreated, positioning them at the cutting edge of agricultural knowledge.

### 5. Challenges and opportunities for knowledge co-creation in agroecology

As outlined in the previous sections, a variety of factors related to diverse knowledge systems, agroecology, and the related collaborative processes and outcomes may emerge as barriers. In the subsequent discussion, we further explore some of these challenges and their potential impacts on the co-creation of knowledge in agroecology, along with some strategies to address them.

Pohl et al. (2010) highlight several challenges in the co-creation of knowledge, including the negotiation of power relations and the integration of different actors' perspectives on the issues at hand. More explicitly, in any collaborative project, some challenges are perceived or actual status and power may affect actors' willingness to take risks, expectations of roles including who is the leader and follower, ability to advocate for one's own needs and priorities, and unequal distribution of benefits and costs. The emergence of power hierarchies within the co-production of knowledge can be minimized by avoiding the privileging of actors from specific disciplines or social positions (Pohl et al., 2010). One method for addressing power dynamics within an approach, such as PAR, is to explicitly discuss the role of invisible actors in power negotiations (Méndez et al., 2017). This may include investors and/or funding entities directly or indirectly involved in projects. Additionally, the interrelation of actors' ideas is a crucial part of the co-production of knowledge, which can be accomplished through devoting time and space for listening and weaving together perspectives throughout the process and within the creation of research outputs.

Another challenge in PAR that may be applicable to the co-creation of knowledge is the complexity of involving many actors and overcoming logistical barriers which may inhibit the adaptation of iterative, participatory processes (Méndez et al., 2017). Throughout the co-creation of knowledge, time is frequently cited as a limiting factor

(Polk, 2015; Rycroft-Malone et al., 2016; Filipe et al., 2017; White and Utter, 2021). There are often tensions in the balance between fully engaging in a relatively time-intensive research process, such as co-creation or PAR, and the urgency to develop and act on innovation. For example, as discussed by Méndez et al. (2017), in reference to PAR, actors are encouraged to actively engage in reflection throughout the process, which emphasizes the importance of being flexible to different actors' time lines for engagement. This extended time line could present challenges in assuring the temporal relevance of research questions and outcomes (Rycroft-Malone et al., 2016). However, this is a central piece of co-creation, which Filipe (2017) defines as “generative processes that are less about delivering predictable impacts and outputs and more about developing new communities, interactions, practices, and different modes of knowledge and value production” (p. 2). Beyond the time lines relevant to academic researchers, consideration of farmer time limitations and fair compensation for their contributions is essential, as noted within our discussions with the Vermont farmer.

Relatedly, in partnerships that include a researcher, one factor that may be driving the urgency in concise and predictable research time lines is the prevailing funding framework, typically pursued and acquired in the form of public or private grants. Often, these funding cycles are relatively short term, which makes sustaining long-term processes difficult. Since research tied to PAR and co-creation is typically funded with soft or time-constrained resources (e.g., a 5-year grant), they are particularly vulnerable to discrepancies in grant availability or funder interest, which can pose challenges for sustaining long-term relationships (White and Utter, 2021). Further, Rycroft-Malone et al. (2016) note that the foundation of co-production lies in maintaining trust and personal connections, which can be negatively affected when there are changes in personnel. Therefore, it is important to have an agreed-upon framework for knowledge transfers in place for both PAR and the co-creation of knowledge.

As identified by Filipe et al. (2017), co-creation benefits from some ambiguity which allows for diverse applications and adaptive exploration, yet foregoing a standardized definition, may complicate the collaborative process. Co-creation may have a different meaning to scientists than to individual farmers and/or farmer organizations. Thus, it is important to seek to understand how various actors interpret co-creation of knowledge and clearly define anticipated co-creation processes and outcomes. Defining (or redefining) the co-creation of knowledge also requires acknowledging the politics of knowledge co-creation in agroecology and addressing related issues of equity, rights, and the ownership of knowledge (Pimbert, 2017).

In considering agricultural heritage and the connected patterns of collective knowledge transfer across generations that have set the foundation of today's co-creation of new knowledge, it may be assumed that data would be inherently open access. However, within agricultural research, there has been an increasing trend in the for-

profit privatization of information (Yost, 2017). Within the co-creation of knowledge, the sociocultural aspects of negotiating expertise and expectations for information sharing must be carefully considered. Previous research indicates that norms of information sharing differ across areas of study. In general, fields reliant on large amounts of relatively homogeneous data repositories, such as genetics, are more apt to information sharing (Reichman et al., 2011). Meanwhile, fields associated with more heterogeneous data sets, such as ecology, have historically lacked incentive to openly share findings, especially before data are analyzed and published. This latter heterogeneity is central to the co-production of localized knowledge; thus, historical patterns would suggest a relatively low incentive for information sharing. However, Yost (2017) frames the unique data generated through the co-production of new agroecological knowledge as a form of “hybrid vigor” with community ownership as a gateway to building from one another’s successes and failures.

A paradigm shift normalizing increased sharing of co-produced knowledge offers an exciting opportunity to increase the accessibility and impact of agroecology. Transdisciplinary scholars are continually proposing solutions to avoid the privatization of data, such as electronic data sharing platforms that ensure the knowledge of co-producers is properly recognized (Hine, 2006; Reichman et al., 2011). Although technology-based collaboration could help unify efforts, it could also exclude communities who do not use electronic platforms (due to choice, access, or otherwise). Additionally, the movement toward open access should be approached cautiously, as there may be an associated increase in data extrapolation that does not honor the complex relationship between actors that is foundational in the co-production of knowledge. In other words, the broadening availability of information access may come with an increased risk of misinterpretation and/or misapplication, especially in the context of hyper-localized knowledge.

Finally, there are expanding opportunities for the co-creation of knowledge to impact the future of agroecology as a science, practice, and movement. For example, Timmerman and Felix (2015) frame agroecology as knowledge-intensive and a means of achieving contributive justice. They relate meaningful work to contributive justice with 5 elements: “acquiring and developing capabilities, recognition as peers, mutual influence, non-redundancy, and self-determination” (p. 529). These share similarities with many of the elements of co-creation discussed above. There is also opportunity for the transformation of academic institutions to foster the elements of co-creation of knowledge, especially across transdisciplinary applications. Vandermeer and Perfecto (2013) advocate for research that seeks to combine the depth and locality of traditional knowledge with the shallowness and generality of modern ecological knowledge to create “the generation of knowledge that is simultaneously deep and general” (p. 86).

Ultimately, based upon our analysis of the factors that facilitate co-creation and our understanding of the

challenges, we find that there is significant potential for co-creation of knowledge in agroecology.

## 6. Conclusion

In drawing on lessons from established approaches in the development, transfer, and application of knowledge, co-creation can provide the opportunity to bring together traditional and scientific knowledge in a transdisciplinary way. Knowledge co-creation is particularly well-suited to applications within the science, practice, and movement of agroecology, given the existing emphasis on participatory and farmer-centered processes and outcomes.

Given the growing interest in participatory research methods, the intrinsic and extrinsic value of integrating and dialoguing across diverse knowledge sets, as well as the need for innovation to address complex issues in agroecosystems, processes that focus on the co-creation of knowledge are increasingly important. The examples we share in this article illuminate areas within agroecology where co-creation of knowledge may occur, including within PAR and related farmer-led and/or farmer-to-farmer approaches. In addition to advancing the understanding of conditions that can promote co-creation, these other processes and outcomes provide insight into potential challenges in co-creation and strategies for overcoming them.

As much as co-creation of knowledge illuminates the known, it also highlights the unfamiliar and areas that require further exploration and development across various settings and actors. This review has drawn on the limited academic literature base on knowledge co-creation, in an effort to collect and build on our collective understanding of the subject. As co-creation of knowledge expands, it is our hope that documentation of other actors’ experiences within co-creation processes becomes more prevalent and accessible, especially cases featuring firsthand farmer perspectives rather than researcher observations. Additionally, we encourage reflection, inquiry, and documentation of co-creation within the academic literature base to continue to evolve beyond top-down information transfer toward collaborative and equitable knowledge development.

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## Author contributions

- Substantial contributions to conception and design: AU, AW, EM, KM.
- Acquisition of data: AU, AW, EM, KM.
- Analysis and interpretation of data: AU, AW, EM, KM.
- Drafting the article or revising it critically for important intellectual content: AU, AW, EM, KM.
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