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A polycentric network strategy for regional diversification of agriculture: theory and implementation

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Widespread and substantial diversification of current agroecosystems appears fundamental to meeting many grand challenges in agriculture. Despite urgent calls for diversification on regional scales, particularly in regions dominated by industrialized, low-diversity agriculture, strategies for diversification on such scales are in early stages of development, conceptually and practically. We outline such a strategy, and its implementation by the Forever Green Partnership, a public-private-NGO coalition in support of agricultural diversification in the U.S. Midwest region. Our strategy supports introduction and scaling of multiple novel crops in a region, which requires development of many interdependent supporting elements, including supportive markets, infrastructure, policy, finance, and R&D. The core of our strategy is development of *sustainable supply chains* (SSCs) for a set of novel crops. We define SSCs as rudimentary systems of these supporting elements for novel crops, linking on-farm crop production to end-use markets while advancing economic, environmental, and social sustainability criteria that are demanded by stakeholders. SSCs provide a scaffold upon which fully-developed support systems for multiple novel crops can be constructed, thus driving regional diversification. SSCs cannot be "built in a day"; rather they must evolve as production of novel crops expands over time and space, and as new challenges and opportunities emerge. Therefore, regional diversification requires a system to sustain this evolutionary process across time and multiple novel crops. We posit that an effective system can be built from two crucial elements: a process of conscious and concerted cultural evolution, and a polycentric network that organizes and supports that process. We outline this system and its conceptual basis, and its implementation by the Forever Green Partnership, and associated challenges and accomplishments. Three years after its inception, the Partnership has attracted substantial resources, developed a polycentric network, and some elements of the cultural-evolution process are in place. However, node development is uneven across the network, hindering its operation. In addition to advancing strategies for regional-scale diversification, the Partnership is seeking to advance conceptual and practical understanding of sustainability transitions in agriculture, and to explore the potential value of conscious cultural evolution in such transitions.

KEYWORDS

agroecology, polycentric governance, social networks, cultural evolution, sustainability transition

Introduction

Major transitions are needed in agriculture to address its grand challenges, including climate change adaptation and mitigation, restoration of soil, water, and biodiversity, enhancement of health through diet, and achieving equity and justice in agriculture, food, and bioproduct systems (Willett et al., 2019; Klerkx and Begemann, 2020; Rockström et al., 2020; Steiner et al., 2020). Diversification of current farm production systems appears fundamental to meeting these goals. Through a wide range of mechanisms, diversification can enable climate-change adaptation and mitigation, support dietary shifts, and improve the condition of soil, water, and biodiversity resources (Lin, 2011; Kremen and Miles, 2012; Bowles et al., 2020; Tamburini et al., 2020). Diversification also creates opportunities to enhance equity and other social dimensions of sustainability, if specific efforts to address social sustainability challenges are encompassed in diversification initiatives.

Herein, we write to advance strategic frameworks for diversifying agriculture at regional scales. The authors are affiliates of the Forever Green Partnership, (2023), a coalition of environmental, agricultural, research, and private-sector organizations working to advance agricultural diversification in the U.S. Midwest region. To guide the work of the Partnership, we have synthesized a regional-diversification strategy from multiple sources, both conceptual and practical, and describe ongoing implementation and assessment of the strategy. Development of such frameworks appears to be in early days, despite growing awareness of the value of diversified regional food systems (Blay-Palmer et al., 2018; Clancy and Ruhf, 2018; Nicol, 2020), and calls for diversification on regional scales (Prokopy et al., 2020). Specifically, we draw on frameworks from the emerging fields of sustainability transitions (Geels, 2019; Schlaili and Urmetzer, 2019; Wyborn et al., 2019), systemic approaches to innovation (Hermans et al., 2019) and the "science of scaling" of agricultural innovations (Barrett et al., 2020; Schut et al., 2020; Wigboldus et al., 2020). We integrate these by applying the emerging theory of conscious and concerted cultural evolution (Cox and Schoon, 2019; Wilson, 2019).

We address diversification at a regional level via introduction and scaling of additional crops in a region; these may be entirely novel crops, or new to the region. There are many barriers to such diversification (Lockeretz, 1988; Meynard et al., 2017, 2018; Jouan et al., 2019; Stefani et al., 2020; Mortensen and Smith, 2020). The fundamental conundrum is that, absent markets, farmers will not grow such novel crops, while without supply from farmers, market demand is unlikely to develop. Beyond markets, novel crops also lack most other pillars of support needed by any established crop: technologies and ecosystems of production (comprising crops, land and soil, and associated biodiversity); post-production infrastructure, and end-use product production; human "capital," including interest and know-how; social and institutional capital (e.g., advocacy groups for the crop); and financial, political, legal, regulatory, and cultural support (Lockeretz, 1988; Montenegro de Wit and Iles, 2016; Blesh et al., 2023). The absence of such supporting elements creates strong 'lock-in' path dependence that sustains established crops (Meynard et al., 2018; Mortensen and Smith, 2020). To introduce and support a novel crop in a region, it is necessary to organize a new *socio-ecological-technical system* for the crop, comprising the above supporting elements.

Socio-ecological-technical systems are integrated sets of biophysical, technical and social elements that function together to meet a societal need (Duru et al., 2015; Markolf et al., 2018; Ahlborg et al., 2019). Construction and scaling of socio-ecological-technical systems for diversification crops is a dynamic, contingent, and inherently risky undertaking, as many different elements must develop and cohere, in an integrated process of innovation and scaling (Jordan et al., 2016; Meynard et al., 2017; Blesh et al., 2023). Importantly, development of certain "pillars" (e.g., novel land valuation and financing mechanisms, Johnson, 2020), will be relevant to multiple novel crops for a region, creating interdependencies in socio-ecological-technical systems development among multiple crops. Therefore, the process of regional diversification can be framed as ***establishment of a mutually supportive set of socio-ecological-technical systems for a set of novel crops***.

Accordingly, our strategy for regional diversification centers on interdependent construction of such supportive systems for each of a set of crops. The core of the strategy is a process of conscious and intentional cultural evolution (Cox and Schoon, 2019; Wilson, 2019), undertaken by a collective of actors relevant to construction of these supportive systems. Recently, this evolutionary approach to cultural change has emerged as a novel approach to sustainability transitions (Brooks et al., 2018; Jones et al., 2020). We apply this evolutionary perspective by viewing socio-ecological-technical systems as evolvable units of human culture that integrate beliefs, values, norms, knowledge, technologies, behaviors, and institutions (Montenegro de Wit and Iles, 2016; Barrett et al., 2020). Specifically, our strategy is designed to drive rapid regional diversification by efficiently evolving ***sustainable supply chains*** (SSCs) for novel crops. As we define them, SSCs are rudimentary socio-ecological-technical systems that link on-farm crop production to end-use markets, while advancing economic, environmental, and social sustainability criteria that are demanded by stakeholders. We propose that SSCs provide a scaffold upon which fully-developed socio-ecological-technical systems can be constructed and scaled, thus driving regional diversification. Below, we present the conceptual basis for this strategy, and then provide case study of ongoing implementation of the strategy by the Forever Green Partnership. We note that while our strategy is applicable to diversification by introduction of novel crops of any sort, the implementation case focuses on a set of perennial and winter-annual crop species being developed by the Partnership (2023).

Sustainable supply chains for novel crops

We define SSCs for novel crops as on-farm crop production and flows of agricultural commodities and ecosystem services that result from these farm activities, and associated institutions and infrastructure. Together, these elements constitute a rudimentary socio-ecological-technical system, consisting of three coupled and interactive subsystems (Duru et al., 2015).

A crop production subsystem comprising farmers and farms producing novel crops

During initial stages of SSC development for emerging crops, this subsystem should consist of spatially-aggregated clusters of farms producing these crops, as clusters provide mutual support and other advantages of aggregation (Manson et al., 2016). Such clustered production can be advantageously situated within areas on the scale

of a small watershed, as modestly-sized agricultural watersheds (*ca.* 10,000 ha) appear advantageous for coordinated implementation of agricultural diversification and conservation measures (Jordan et al., 2018; Ranjan et al., 2019).

A post-production commodity subsystem comprising post-production commodity supply-chain actors and associated infrastructure

This subsystem is an inter-organizational system that efficiently and effectively manages flows of material, information, and capital associated with the production of products, to meet economic interests of participating organizations while advancing environmental and social sustainability (Morais and Silvestre, 2018; Westermann et al., 2018). It links farm commodity production to end-use markets, and includes physical infrastructure (e.g., processing or storage facilities), and organizations and institutions involved in supply-chain operation or governance.

A socio-ecological subsystem comprising natural-resource management actors and natural resources affected by the supply chain

This subsystem comprises clusters of farms producing novel crops that produce some environmental benefit (e.g., improved condition of soil, water, and biodiversity resources), and one or more "customer(s)" for these benefits, e.g., a city affected by attributes of water in a watershed. The customer(s) will interact with farms to compensate them for these benefits, e.g., by monetary subsidies for new crop production. This subsystem also includes any non-local customers for environmental benefits (e.g., for soil carbon storage) and organizations and institutions involved in governance of relevant natural resources and systems for compensation (e.g., payment-for-ecosystem-service programs).

Our diversification strategy aims to drive regional diversification by multi-sector collective action to develop SSCs that advance economic, environmental, and social sustainability criteria that are demanded by stakeholders. As is broadly recognized (Hermans et al., 2019; Barrett et al., 2020), collective action across public, private, and NGO/philanthropy sectors is critical to sustainability transitions, such as regional diversification.

Building Sscs for regional diversification of agriculture: a system for interdependent development and scaling

Development and scaling of SSCs is a complex challenge

We presume that to attract and inspire broad collective action to advance regional diversification, SSC establishment and operation must provide multiple economic, environmental, and social benefits (Peterson, 2009; Boström et al., 2015). SSCs that produce this full range of sustainability benefits cannot be "built in a day." There are many unknowns about SSC design and operation (Boström et al., 2015; Wigboldus et al., 2016), and SSCs must evolve as production of novel crops expands over time and space, adapting to new geographies, and to new challenges and opportunities that emerge as scaling proceeds (Schut et al., 2020). Moreover, building fully supportive socio-ecological-technical systems for novel crops—including knowledge, economic, political, legal, and cultural domains—construction of fully-supportive systems is likely to be a prolonged process requiring a multiple evolutionary steps (Cooley and Papoulidis, 2017; Geels, 2019; Wilson, 2019; Barrett et al., 2020), via an iterative, learning-intensive process of prototyping, evaluation, and improvement (Seyfang et al., 2014; Gurzawska, 2019; Wilson, 2019; Barrett et al., 2020).

A development and scaling system for SSCs

To advance regional diversification by development and scaling of SSCs for multiple novel crops, effort must be sustained across crops, scales of implementation, and time. Drawing on a range of current models for scaling (Gurzawska, 2019; Tomich et al., 2019; Wilson, 2019; Woltering et al., 2019; Schut et al., 2020), we posit that a development and scaling system for SSCs can be built from two crucial elements. These are 1) active support of a process of intentional and conscious cultural evolution (Cox and Schoon, 2019; Wilson, 2019); and 2), a polycentric network (Carlisle and Gruby, 2019) that supports that process.

Developing SSCs through intentional and concerted cultural evolution

Recently, intentional facilitation of cultural evolution has emerged as a strategy for meeting complex sustainability challenges (Brooks et al., 2018; Wilson, 2019). The idea is to support cultural evolution by a selective process that supports desirable and replicable cultural innovations that meet sustainability challenges. For regional diversification of agriculture via novel crops, the relevant cultural innovation is in the structure and functioning of SSCs. Desirable SSC variants more efficiently and effectively advance sustainability goals of stakeholders. Such cultural evolution can be facilitated by creating variation through organized innovation and experimentation, imposing selection by "rewarding what works" through differential provision of resources, financial or otherwise (Cooley and Papoulidis, 2017; Sengers et al., 2019; Wilson, 2019; Barrett et al., 2020), and by supporting replication of favorable variants. We propose that, if undertaken collectively and in concert, and facilitated for efficiency and rapidity, these intentional processes of variation, selection, and replication will accelerate SSC development.

Facilitation of this evolutionary dynamic begins by supporting a cross-sector group in defining its goal: i.e., a paradigm of a fully-developed SSC for a novel crop, defined in terms of economic, environmental, and social aspects of sustainability. Once defined, prototypic supply chains can be evaluated against the goal, and supporting resources rewarded accordingly. As implemented in the Forever Green Partnership (described below), this group is a multi-sector collaborative, representing a range of societal sectors that have interests in diversification of a regional agriculture, and the ability to aggregate resources to support promising prototypic supply chains.

Variation is essential to evolution. Therefore, facilitation of SSC evolution should focus on generating variation relevant to the systemic SSC goal. This can be accomplished by organizing a system for creating and pilot-testing novel supply chains that address the systemic

SSC goal. Generally, such novel supply chains will integrate multiple innovations drawn from multiple domains, including the technical, social, organizational, and conceptual (Leeuwis and Aarts, 2011; Barrett et al., 2020). In the Forever Green Partnership, this integration is supported by an ongoing forum for persons professionally engaged in such integrative SSC innovation, as described below.

Finally, replication of selected variants is needed in any evolutionary process. Facilitation must ensure efficient replication of novel supply chains that advance toward the SSC goal. In practice, such replication can be accomplished by adding strong communication and "incubator" aspects to an integrative innovation forum, so that interested parties can develop new supply chain prototypes—e.g., for new crops or in new regions—built on successful novel SSCs.

If these elements of selection, variation, and replication can be established, closely coupled, and sustained over time, then an ongoing process of cultural evolution will drive SSCs toward the systemic goal. What is needed to establish and sustain these conditions, in practice? We propose that a polycentric network can well serve this purpose.

A polycentric network for efficient and forceful evolution of SSCs

Polycentric networks are emerging, in theory and practice, as a strategy for addressing complex sustainability challenges such as regional diversification of agriculture. The essential idea, quoting Ostrom (2010), is development of *"complex multi-level systems to cope with complex, multi-level problems"* (Ostrom, 2010; Dorsch and Flachsland, 2017; Carlisle and Gruby, 2019). Intentional concerted cultural evolution of SSCs is certainly such a problem, and therefore we posit that a multi-level polycentric network (Figure 1) can be designed to support the cultural evolution process outlined above. It is clear that cooperative cross-sector and cross-scale networks can advance innovation and sustainability transitions in agri-food systems (e.g., Blesh and Wolf, 2014; Bui et al., 2016; Home et al., 2017; Meynard et al., 2017). In particular, such networks can bring a range of complementary innovations together (e.g., novel diversified farming strategies and novel institutions) to advance agricultural socio-technical systems, typically at pilot scales, and to advance scaling of these systems (Bui et al., 2016; Home et al., 2017; Meynard et al., 2017). Most commonly, such networks have largely functioned as singular entities, focusing on development of place-based socio-ecological-technical systems (Melchior and Newig, 2021). In contrast, the polycentric network described below is conceptualized as a regional structure, engaging multiple networks operating at multiple scales, in order to support and systematize production, piloting, refinement, and possible scaling of multiple socio-ecological-technical systems in pursuit of agricultural diversification on regional scale. This project thus provides an additional case of deliberate experimentation with polycentric networks for sustainability transitions in agriculture (Marshall, 2009; Fasting et al., 2021; Heckelman et al., 2022). These reported cases, while different in many respects, aim to form systems of cooperation and mutual support among local-scaled sustainability networks and networks acting at broader scales. Therefore, polycentric networks can be seen as an effort to build on the successes of transition networks built around a single place-based project, by engaging multiple local-scaled networks in a polycentric "network of networks." The goal is to provide particular benefits that emerge from effective polycentric structures, i.e., enhancing network-scale learning, innovation, and other collective action, and supporting local self-determination in transition processes (Dorsch and Flachsland, 2017; Barrett et al., 2020). Similar work, if not explicitly framed as polycentric, is embodied in La *Via* Campesina (Rosset et al., 2019), and other extensive agroecology scaling networks (Mier y Terán Giménez Cacho et al., 2018).

For a multi-level polycentric network to support the cultural evolution process, it must provide a goal-setting and resource-provision group: i.e., a consortium of actors that can determine a shared goal for diversification of a region by novel crops, aggregate resources, and provide those resources to support emerging SSCs that best advance the goal. This consortium requires participation by actors that can command and aggregate resources, e.g., managers of corporations and firms, public institutions such as water infrastructure or economic development agencies, and NGOs, such as environmental NGOs. For example, private firms can actively cultivate markets for products of diversification crops that advance sustainability goals. Relevant resources include financial capital, and also include political capital, moral authority ("soft power"), and "integrative power" (ability to articulate compelling visions and bring actors together in collaborative efforts; Boström et al., 2015; Wigboldus et al., 2016; Geels, 2019). The principal incentive for participation is collective agency: the ability to achieve goals together by aggregating power across sectors, to better pursue their common interests in diversification.

At an intermediate level in the polycentric network, a system is needed that focuses on the variation and replication dimensions of managed cultural evolution. These functions can be provided by a consortium of actors—the integrative innovation forum described above—that can generate variation oriented to the SSC goal, assess performance of variant SSCs relative to the goal, promote replication of better-performing variants, and facilitate ongoing generation of new variation. This group should be drawn from actors that are actively involved in innovation, and in integration of innovations into novel co-innovation structures (Bui et al., 2016; Kivimaa et al., 2019), with an emphasis on enabling the "bundling" of complementary innovations in effective combinations (Barrett et al., 2020). Actors charged with innovation within dominant institutions in public, private, and NGO sectors are also key participants. We propose that such actors have collective ability to efficiently devise, test, and to provide nuanced evaluation of prototypic SSCs, as envisioned by Barrett et al. (2020). Moreover, by sharing their evaluations with the goal-setting and resource-provision group, they enable that group to carry out its key function of rewarding high-performing SSCs.

Finally, there is a third level in the polycentric network (Figure 1): innovation actors in a wide range of domains relevant to agricultural diversification. Emergence of key elements of SSCs frequently results from innovation at local scales that leverages creativity and local knowledge (e.g., building the base of supply chains by locally-tailored integration of novel crops into existing farming systems). These domains include development of new crops and new agricultural production systems, but also include supply-chain infrastructure, end-use innovation, and other economic, social, organizational, and policy innovation (Blesh and Wolf, 2014; Bui et al., 2016). In the context of agricultural diversification, such actors are increasingly organized in crop-specific networks that are focused on scaling of particular crops for diversification, via coupled and comprehensive innovation strategies (Meynard et al., 2017).

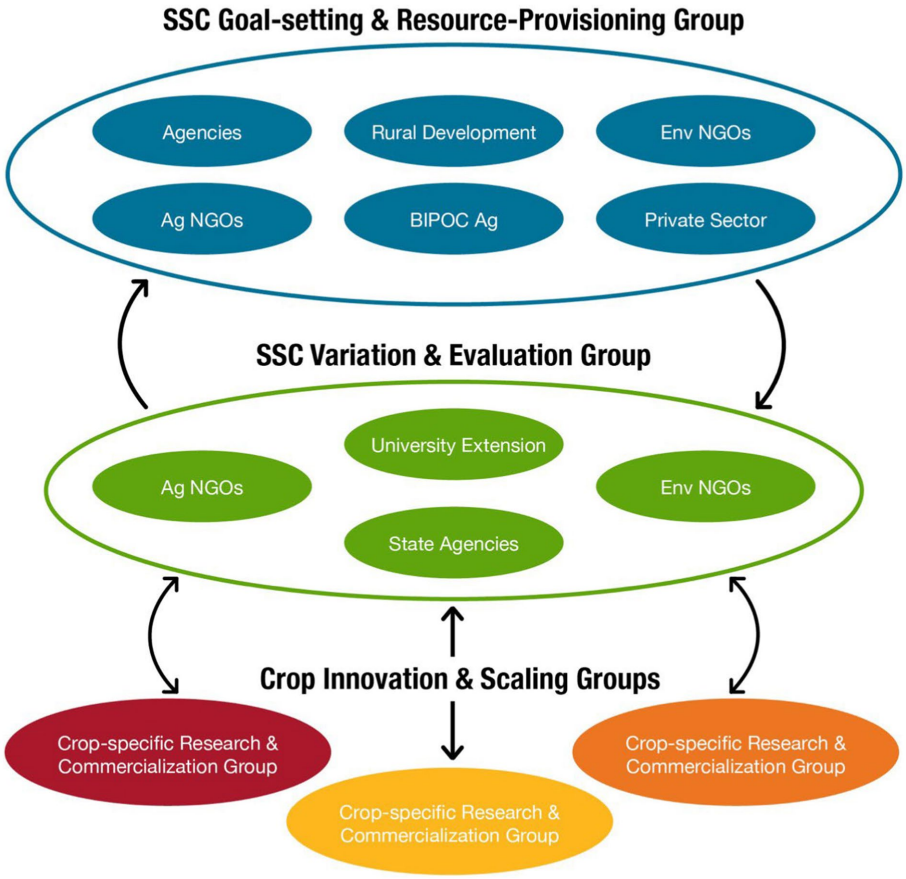

FIGURE 1
Conceptual model for polycentric network for evolution and scaling of SSCs. The network has three levels, as defined in text. Two levels are groups: a goal-setting and resource-provisioning group articulates goals for SSCs, and provides resources to support SSCs that advance its goals. This group is multi-sector, with relevant sectors indicated, as examples, including agriculturalists identifying with Black, Indigenous, and People of Color (BIPOC Ag), and environmental non-governmental organizations (Env NGOs), and agricultural non-governmental organizations (Ag NGOs). The SSC variation and evaluation group informs goal-setting/resource provisioning groups regarding "what works" in SSC development. This group unites a range of SSC innovators for exchange of SSC innovation and development approaches, and collective evaluation of these. This group is also multi-sector; again, relevant sectors are indicated as example. Crop-specific research & commercialization groups develop crops and implement SSCs for these crops. The SSC variation and evaluation group is informed by and provides feedback to crop-specific research & commercialization groups. Interactions occur between the goal-setting and resource-provisioning group and crop-specific research & commercialization groups but are less frequent and intense than the interactions described above.

An implementation case: the Forever Green Partnership

The Forever Green Partnership is an intentional experiment in applying the conceptual models outlined above in a project of regional diversification. This case study of the Partnership is intended to contribute to both the theory and practice of those engaged in the scaling of novel crops. Case studies allow researchers and practitioners to examine factors that influence a unit of analysis over time (Flyvbjerg, 2011). We use qualitative data (interviews and observations), aiming to support readers in forming naturalistic generalizations, i.e., transfers of knowledge that occur within the.

reader and their context (Stake and Trumbull, 1982). Such generalizations are based on context-specific settings and depend on the reader to apply the learnings, findings, and implications from the case study to their experiences (Stake, 2006). Specifically, we highlight the origins of the Partnership, its present structure and functions, and comment on its progress to date. Our discussion of progress is informed by semi-structured interviews with members of the two major nodes of the Partnership network, which were conducted and analyzed by the Partnerships' professional evaluators (co-authors Miller and Noble) during summer 2021 and summer 2022, *ca.* nine and 21 months, respectively after the key nodes of the Partnership had been established by an organizing group. Interviews explored understandings of the node that the interviewee was participating in, interactions with other nodes, and the nature and functioning of the Partnership as a whole. Interviews were conducted with 9 of 14 members (2021) and 9 of 18 members (2022) of the Strategic Steering Committee (see below), and 10 of 16 members of the Learning and Experimentation Network (see below). Interviews were recorded, transcribed, coded, and analyzed using qualitative methods. We have also drawn on observations of meetings of both nodes, which we attended as participant observers, recorded, and transcribed.

Context and diversification strategy

The Mid-Continent of North America is one of the most productive agricultural regions of the world, but cropping systems are dominated by short-lived summer annual crops. These systems leave soil exposed for much of the year, resulting in degradation of soil and biodiversity (Asbjornsen et al., 2014; Prokopy et al., 2020). These impacts threaten long-term food production in this global breadbasket, which may also be reduced by effects of climate change. Moreover, predominant cropping systems have major impacts on drinking water (Temkin et al., 2019), and diminish other ecosystem services related to water (Brauman, 2015), such as navigation and recreation. To protect the region from these mounting threats, and to sustain a significant element of the global food system, regional agricultural diversification is essential (Prokopy et al., 2020). The Forever Green Partnership has formed to pursue a particular diversification pathway: making farmland "forever green" with a set of crops that advance continuous living cover (CLC) agriculture in this region. CLC agriculture denotes agricultural systems in which there are living plants and roots in the ground throughout the entire year. Crops that advance CLC in this region include winter-hardy cover crops, which are generally defined as annual crops grown to enhance soil, water, and biodiversity without harvest of any agricultural commodity (e.g., seeds or biomass), other winter-hardy crops that produce such commodities, and perennial crops. Specifically, the Partnership is supporting development and commercialization of a portfolio of such crops for this cool-temperate region of North America, aiming to enhance a wide range of environmental and economic benefits to the region (Asbjornsen et al., 2014; Schulte et al., 2017). A leading developer of these crops is Forever Green Initiative (2023), a consortium of crop developers that is central to the Partnership. The Initiative is carrying out collaborative crop R&D efforts that span genomics, plant breeding, agronomy and agroecology, post-harvest handling and value-added processing.

Formation of the Forever Green Partnership

The Partnership was formally launched in 2018 by the co-directors of the Forever Green Initiative and several conservation groups (Friends of the Mississippi River and Minnesota Environmental Partnership) with financial support from the Minnesota Clean Water Council (a multi-sector governing body charged with distribution of public monies dedicated by statute to improving water resources in Minnesota). These conservation groups had grown increasingly interested in market-based diversification of agriculture as a pathway to meeting their water conservation goals. To pursue this vision, they proposed a coalition of environment, agriculture, research and business organizations in support of agricultural diversification via CLC agriculture. This coalition was also of interest to the Forever Green Initiative, as a complement to its crop R&D. After deliberation, a working charter for the Forever Green Partnership was established by late 2019. The charter established a "Strategic Steering Council" and "Learning and Experimentation Network" as two novel core elements of the Partnership, complementing the R&D capacities of the Forever Green Initiative. These two groups were organized in 2020, and began meeting monthly in the second half of that year. In 2019, the Forever Green Initiative received grant funding that supported commercialization of the most advanced crops via development of markets, and supply chains to serve those markets. The current structure and activities of the Partnership (Figure 2) are described below, followed by a reflective account of the Partnership's progress to date.

Strategic steering council

The Council is intended to function as the goal-setting and resource-provision group of the polycentric network described above—i.e., a consortium of actors that can set a goal for CLC agriculture, aggregate resources, and promote SSCs that best advance the goal, by differential allocation of these resources. At present, the group includes 17 active members (Table 1), drawn from state government, non-profit advocacy groups representing a range of interests including conservation, regional mainstream agriculture, rural community development, historically marginalized groups, the private sector, and the research and commercialization work of the Forever Green Initiative. The group aims to broaden the base of support for CLC agriculture across a wide range of societal sectors represented in the Council, so that these sectors can provide political, financial, and other forms of concrete support for advancing such agriculture. This support is intended to be provided selectively, providing support to SSCs and other CLC scaling efforts that accord with the Council's shared vision for CLC agriculture. In interviews, members described themselves as wanting to be of use, experienced in thought and action leadership, and willing to offer their reputation, knowledge, capabilities, connections, and other resources to advancing CLC agriculture. Specifically, activities included discussion of goals and values (including social visions) for CLC agriculture, in pursuit of a shared vision for CLC agriculture in the region. The group has also held many learning sessions with innovators in relevant sectors (e.g., in rural development, and in new strategies for financing CLC agriculture) to develop shared understanding of these innovations and potential for engaging associated sectors in efforts to advance CLC agriculture. After these formative activities during the first year of operation, the Council turned its hand to definition and implementation of an agenda of "ambassadorship and advocacy" by which the multi-sector base of support for CLC agriculture could be broadened and deepened.

In interviews after the first year of operation, some Council members expressed appreciation for the Council as a forum for robust intersectoral exchange and cooperation around common interests in CLC agriculture. Illustrating this, one council member shared, "the original concept was that we would, through this interdisciplinary, iterative sort of workshopping model, we would bring all that expertise and come up with more of a synthetic pathway." Another underscored the benefits of the diverse group, stating "there aren't that many organizations that have that kind of potential reach across so many sectors. Summing up the unique potential of this group, one member shared, "[my] personal excitement is that I cannot find another group like this…that is building something and not just researching."

While members see potential in the Steering Council, they also expressed frustration about barriers to working jointly, i.e., as a council, to scale CLC agriculture. Perceived barriers included lack of clarity about the role and autonomy of the Council within the Partnership, uncertainty about the ability of Council members to influence the strategic actions of the Partnership, and insufficient understanding of needs of researchers and commercialization staff. As

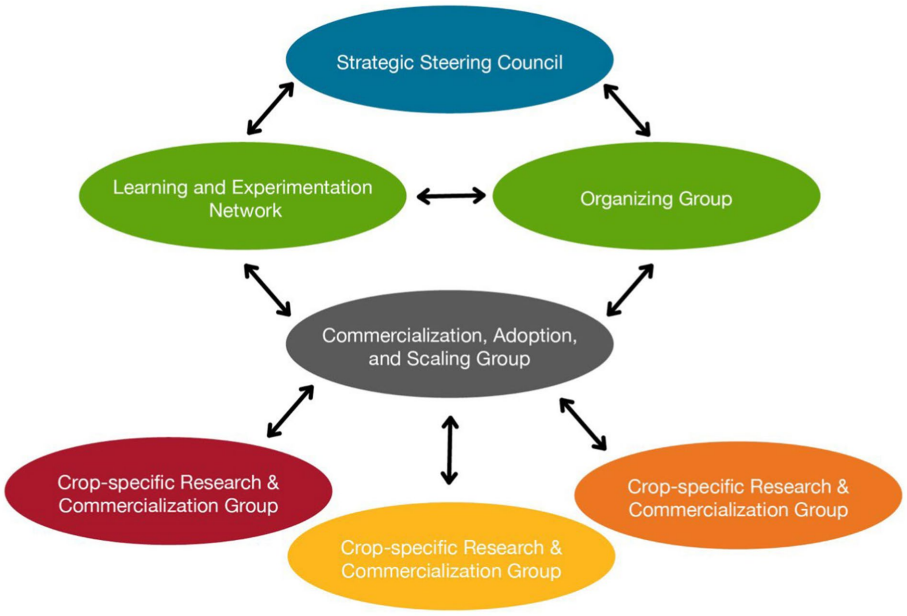

FIGURE 2
Current State of the Partnership. As presently implemented, the Partnership's polycentric network includes a Steering Council engaged in advocacy and ambassadorship in support of CLC agriculture, a Learning and Experimentation Network engaged in co-learning and action research on scaling CLC agriculture, a Commercialization, Adoption, and Scaling group building pilot supply chain projects, a set of crop-specific R&D teams advancing particular CLC crops, an organizing group, and a number of working groups addressing policy development and politics, equity and inclusion, and strategic communication. Major interactions are illustrated with two-headed arrows; for simplicity, working groups are omitted. Other inter-group interactions occur, but are less frequent and intense than those illustrated in the diagram.

one member stated, "I think it's important that everybody be on the same page about what their role is, and what we are trying to accomplish with the [Steering Council]. And I do not think we quite have that, yet." Another member spoke to the need to better understand the evidence behind the social, environmental, and economic benefits.

In response to the role uncertainty, over the course of the second year, the conveners of the Steering Council guided conversations and offered content to help the group determine how to operationalize its role in advocacy. There was largely agreement that the Steering Council's role in advocacy should be focused on building collaborative relationships with particular sectors around mutual interests in CLC agriculture. Several work streams came into focus during year 2, and after some experience attempting to launch such Council initiatives, it became clear that additional staff capacity was needed. Interviews after the second year indicated some appreciation of learning about topics and perspectives that are "outside of the circle" in which most Steering Council members operate. However, barriers to effective action by the Council were still perceived, namely the continued desire to firm up the Steering Council's purpose and the need to operationalize the advisory role. One member illustrates this by stating "There should be a 2-way conduit…these members should be taking their knowledge of the fears, aspirations, biases of their sector and bringing that to the Partnership so that if we are going astray so that we would know that." Other members spoke of the need to put boundaries around the scope of the conversations and clarify priorities: "We are opening up these wicked problems ––while I really like those, I am wondering if we can bring this back to….how do we promote winter barley. Sometimes I think my mind sits in the area of 'the next steps of barley is this'….how do we move from niche to bigger." In December, 2022, the Steering Council clarified that its purpose is to "advance Continuous Living Cover agriculture by contributing constructively to the development and sustainable commercialization of new cropping systems by: (1) Providing feedback to the Forever Green Initiative and the Partnership about strategic decisions, emerging issues and opportunities, and timely questions; (2) Providing resources to the Forever Green Initiative (relationships, financial, and other resources); (3) Acting as an ambassador for the Forever Green Initiative. To support this clarified role, in the coming year, leadership of the crop research and commercialization teams will identify emergent topics that would benefit from strategic input from the Steering Council. Through these developmental efforts, council members have advanced the Steering Council toward its intended goal-setting and resource-provision roles in the cultural evolution system outlined above—in particular, members have agreed on a goal for CLC agriculture—but their resource-provision roles has not yet been substantially implemented.

Learning and experimentation network

This group is intended to serve as the intermediate level of the polycentric network, focusing on the variation and replication dimensions of intentional cultural evolution. The Learning and Experimentation Network (referred to henceforth as the Network) is a group of persons professionally engaged in commercialization and scaling of CLC crops via market and supply-chain development. Members (16 as of this writing) are affiliated with five different organizations or advocacy groups (Table 1), and work together to share information and experience from their work to scale these crops. In parallel to the Steering Council, the Network began its work by sharing notions and visions about the nature of CLC agriculture, and then

TABLE 1 Participants in Forever Green Partnership's Strategic Steering Council and Learning and Experimentation Network, during 2020–2022.

Sector and Location	Organization	Participation
Agribusiness, Minnesota	Agribusiness (retired former executive)	Steering Council
Agribusiness, Minnesota	The Plant Pathways Company	Steering Council
Agribusiness, Minnesota	Worthwhile Ventures, Inc.	Steering Council
Agriculture NGO, Minnesota	Agricultural Resources Utilization Institute	Learning and Experimentation Network
Agriculture NGO, Minnesota	Intertribal Agriculture Council	Steering Council
Agriculture NGO, Minnesota	Kilimo Minnesota	Steering Council
Agriculture NGO, Minnesota	Minnesota Corn Growers Association	Steering Council
Agriculture NGO, Minnesota	Minnesota Farmers Union	Steering Council
Agriculture NGO, Minnesota	Naima's Farm	Steering Council
Climate NGO, Illinois	Solving for Pattern	Steering Council
Climate NGO, Minnesota	MN350	Steering Council
Environment NGO, Minnesota	Friends of the Mississippi River	Steering Council
Environment NGO, Minnesota	Minnesota Environmental Partnership	Steering Council
Environment, University Extension, Minnesota	Green Lands Blue Waters, University of Minnesota	Steering Council
Government, Minnesota	Minnesota Department of Agricullture	Steering Council
Research and commercialization, Wisconsin	Michael Fields Agricultural Institute	Learning and Experimentation Network
Research and commercialization, Wisconsin	Savannah Institute	Learning and Experimentation Network
Research and commercialization, Kansas	The Land Institute	Learning and Experimentation Network
Research and commercialization, Minnesota	University of Minnesota	Steering Council, Learning and Experimentation Network
Research and commercialization, Wisconsin	University of Wisconsin	Learning and Experimentation Network
Rural community development NGO, Minnesota	West Central Initiative	Steering Council

proceeded to a series of sessions focused on dialog on key aspects of day-to-day work. Topics have ranged widely, including framing and narrative for CLC agriculture, innovations in "green" finance, and developments in agricultural cooperatives. In interviews after the first year of operation, Network members voiced much appreciation for the learning and support that the group provided. They also expressed much uncertainty about the purpose and function of the Network, its role in the Partnership, and its autonomy. One Network member expressed this in saying, "I do not think there's broad understanding in the Network of what the Network is supposed to be for or do. And so, that's where I see the disjointed…confusion." Several members spoke to the potential they saw in the Network; for example, one member stated, "How could that team spend 2 h every other week to really inform one another what we are doing, solicit input on key decisions that I think they would have a good perspective on, get access to resources and relationships that we would not otherwise have, and start leveraging that."

In the second year of its operation, the Network began a series of discussions focused on evolving challenges in commercialization and scaling, with each meeting featuring a central challenge narrated by a member. Recently, the Network has agreed to pursue an explicit program of action research (Touboulic and Walker, 2016) on particular challenges and opportunities in commercialization and scaling of CLC crops. In a group reflection conversation after the second year of operation, Network members articulated a clearer sense of the group's purpose, value, and role in the Partnership. One member commented, "I truly see some really beautiful trust that has been built between this entire group. This is not an easy place to be vulnerable but we know that vulnerability drives innovation and risk taking." This statement is indicative of an apparently shared sentiment that trusting relationships have developed in the Network, and that this trust permits candid and vulnerable discussions of issues in scaling work. These trusting relationships were also seen as providing provided peer support that could be called on when needed. For instance, when one Network member was a panelist alongside another Network member, she felt she did a better job sharing her message because of the trust and collegiality she had built with this other person through the Network. Members also voiced a clearer sense of the Network's identity and purpose: a forum and incubator for sharing experiences and insights in the work of scaling CLC agriculture, across a range of crops, ecosystems, and institutions.

Looking forward, the group was eager to share its emerging insights about its work, which they view as poorly understood by most other actors in the Partnership and agriculture generally. For example, the group hopes to influence policy development and other activities of the Partnership, such as strategic communications. These activities, if implemented, will help the group carry out its envisioned functions in the regional diversification strategy, namely to facilitate the variation and replication dimensions of intentional cultural evolution. To date, these activities are only partially implemented: the professional exchanges within the group are likely to be generating variation, as members transfer ideas for pilot-scale systems. For example, steward ownership (Sanders, 2022), an innovation in intellectual property ownership, originally applied to one crop, has recently been applied to another, as a result of communication among Network members. However, replication functions, and interactions

with the Steering Council leading to differential resource provision have not yet been robustly implemented.

Commercialization, adoption, and scaling group

As CLC crops developed by the R&D efforts of the Forever Green Initiative near commercial readiness, the Forever Green Commercialization, Adoption, and Scaling Group supports piloting, adoption, and scaling of these new crops and systems by growers, supply chain partners, end-users, and others. This group, now comprising five staff committing 100% effort, organizes and provides strategic technology transfer, risk-sharing, technical assistance, communication of technical properties, enterprise development, policy innovations, and extensive cross-sector partnership. At present, these activities focus primarily on the most commercialization-ready of Forever Green's portfolio of crops, including Kernza® perennial grain, the 'cash cover crops' pennycress, winter camelina and winter barley, perennial flax, elderberries, and hybrid hazelnuts. For these crops, pilot SSCs (Table 2) are being organized at a range of sites in the Upper Midwest region of the U.S. In each instance, this group convenes multiple supply-chain stakeholders—including end-use and intermediary firms, farmers, clients for environmental benefits produced by the crop, and other stakeholders—in collaborative efforts to develop a spatially-concentrated cluster of production of the focal crop, in a setting where there is active interest in the economic, environmental and social sustainability benefits that such a cluster could potentially provide. These clusters of production enable all parties to pilot and "debug" systems and innovations needed to create viable SSCs, e.g., post-production infrastructure or innovative public policy support for CLC agriculture. These activities are closely coordinated with the R&D teams for each of the above crops.

R&D teams

At present, *ca.* 75 scientists, primarily located at research universities in the Midwest region of the US, are developing 16 perennial and winter annual crops and associated cropping systems, and post-production handling and value-added processing systems, in affiliation with the Forever Green Initiative. Each effort is organized as a working team focused on a single crop or small group of crops, and includes geneticists, plant breeders, agronomists, environmental scientists, food scientists, and commercialization experts.

Ad-hoc working groups

The Partnership includes a number of working groups that have been developed since inception in 2019, all of which embody the cross-sector and cross-scale interactions integral to building and implementing a polycentric network for regional diversification. Working groups include an organizing group that provides overall coordination to the Partnership, and a newly-formed strategy group, with members drawn from most of the groups described above. The strategy group is charged with refining the strategy of the Partnership as a whole, and improving working relationships among the parts of the Partnership so as to enhance effective pursuit of its strategy. Another key group is striving to insure that commercialization and scaling of CLC agriculture proactively addresses justice, equity, and inclusion issues in agriculture. There are also standing groups for strategic communications, and a political working group that engages in policy advocacy and lobbying.

Progress of the Forever Green Partnership

The Partnership was implemented *de novo* in 2019. As noted, initial design, implementation, and operation of the Partnership were guided by the conceptual models outlined above. These models have been largely embraced, as working hypotheses, by the organizing group that provides overall coordination to the Partnership.

Challenges

Formation of a novel polycentric network is clearly an ambitious and inherently challenging project, and is expected to require some years of development before the network becomes effective in pursuit of its goals (Hileman and Bodin, 2019). At the time of writing, the Partnership is not yet fully functioning as a polycentric network for conscious cultural evolution, as envisioned in the regional diversification strategy outlined above. In essence, the Partnership has not yet developed certain "enabling conditions" that are important to effective polycentric networks (Carlisle and Gruby, 2019), such as agreed-upon rules of operation, cross-scale deliberation and learning, and mechanisms for accountability, all of which are important to facilitation of cultural evolution. These conditions appear essential to the processes of conscious cultural evolution (variation, selection, and replication of SSCs). These enabling conditions require agreements—and sustained collaborative activities—across nodes in the network, which highlights node development as a key milestone in the formation of effective polycentric networks. Ostrom's core design principles (Wilson et al., 2013) for effective cooperative groups offer a helpful touchstone for assessing development of effective network nodes. Principles most relevant to the initial development of individual network nodes include a shared understanding of a nodes's purpose and key activities, and processes for decision-making and distribution of costs and benefits of group participation. Achieving and implementing these shared understandings is likely to be complicated, particularly when a node represents a voluntary association in a "community" situation (Cabrera et al., 2018), as opposed to an organization whose leadership can mandate participation.

As may be expected from these considerations, development of the nodes of the Partnership has been complicated and slow. Interview data show that, for many participants in these nodes, shared understanding of each node's purposes and activities—and of interactions among nodes, and of the Partnership as a whole—has been slow to develop. Importantly, many participants express strong interest in taking action, and have been somewhat frustrated by deliberative activities, particularly in the Strategic Steering Council.

An important challenge is developing the nodes as semi-autonomous groups that are self-directed and self-governing, as opposed to being convened and directed by the project organizers, with relatively passive participants. In principle, this "semi-autonomous" attribute is critical to the ability of a node to function in a polycentric network on a sustained basis (Wilson et al., 2013). An important strategy for meeting this challenge has been to find ways for the node's activities to be valuable to participants even if the polycentric network is not yet functioning as a whole. Progress has been made in this respect for the Learning and Experimentation Network, whose members have actively embraced the opportunity to exchange experiences, information, and strategies regarding their work of developing new markets and supply chains for continuous-living-cover crops. This has been less successful for the Strategic

TABLE 2 Pilot supply-chain projects for various continuous-living-cover crops associated with the Forever Green Partnership in various US states (Illinois, IL; Iowa, IA, Kansas, KS; Minnesota, MN; Montana, MT; North Dakota, ND; South Dakota, SD; Wisconsin, WI).

CLC Crop	Location	Features	Number of farmers	Number of supply chain actors	Spatial extent
Kernza Perennial Grain	MN, KS, WI, MT	Technical and financial support for geographical clusters of piloting farms, farmer production cooperative, novel public (MN) seed capital fund for value-added enterprises CLC	82 approved growers in US; roughly 30 growers in MN	3 seed sources, 1 MN seed processor, 1 WI seed processor onboarding, 1 WI grain processor onboarding	~2,500 ha total licensed total, ~900 ha in MN (as of Oct 22)
Winter Camelina	MN, SD, ND, IA	Technical and financial support for geographical clusters of piloting farms	9 MN growers in 2021/22 pilot project;	2 seed sources, 2 seed processors, 4–6 major commercial actors conducting internal pilot production, 1 for-profit biotech business offering contracts	~40 ha in 2021/2022 pilot, 100 ha acres of industry pilots planted in 2022, multiple + 4,000 ha pilots planned for 2023
Hybrid Hazelnuts	WI, MN, IA	6 clusters of growers across Upper Midwest, pilot processing plant in Ashland, WI, network of leading 'Go-First Farms' in each cluster; piloting innovative germplasm ownership and land-access financing	50–75 growers across clusters, small number of growers and researchers (~10) account for roughly half of all production.	3–5 producer groups, 4 nurseries conducting propagation, one publicly-owned pilot processing line, 1 retail products brand, direct-to-consumer sales by growers and modest inclusion of Midwest-grown hazelnuts in limited-distribution food products	40–80 ha of hybrid research, early commercial, and hobbyist production
CLC Crop	Location	Features	Number of farmers	Number of supply chain actors	Spatial extent
Perennialized systems, including managed grazing (Grassland 2.0)	Primarily WI (some work in Driftless Region of IA, IL, and MN)	Partnering with farmer and citizen-led watershed groups to build shared 'Story of Now' and Vision for the future, and to identify and take action on pathways to the future.	Currently 10–15 farmers engaged in the grass-fed meat supply chain work in the Dritless started in 2022. Building out network in 2023. Custom dairy heifer grazing network in central/north-central WI ramping up. Currently 6 farmers, expanding in 2023.	Five local "learning hubs" built on watershed based groups. Two supply chain development pilot projects covering 3 of the 5 Learning Hubs. For the meat supply chain work in the Driftless, engagement with 3 processors in SW Wisconsin and 1 beef aggregation and sales cooperative that also has some processsing.	~250 ha in Custom dairy heifer grazing network
Winter barley	MN	Early commercial scaling of new winter barley lines in partnership with regional seed companies and malting industry	10–20 at launch of first winter barley variety	Two seed company partners, early engagement with major (global) maltsters located in the region	Unsure

Steering Council, but there has been increasing energy around taking individual and collective action as advocates and ambassadors for continuous-living-cover agriculture and the Forever Green Partnership. The Commercialization, Adoption, and Scaling node has achieved self-direction and organization.

Crucially, we believe that node development has been limited by lack of resources for two key developmental activities. First, we have lacked capacity to engage with node participants in ongoing one-to-one discussions around their interests in node participation, questions, and concerns. These discussions appear important to stay in touch with participants as they engage in the slow, ambiguous, and complicated work of node development. Second, there has also been a lack of resources for organizing and supporting cross-sector and cross-scale activities of the Partnership as a developing polycentric network. Such activities include information-sharing and other learning, carrying out initiatives that engage multiple nodes, and formation of shared understanding regarding collaboration between nodes in a polycentric network. Certainly, these activities and interactions are the lifeblood of effective polycentric networks (Carlisle and Gruby, 2019). In interviews, Steering Council members expressed that these activities were highly important to their ability to offer concrete support to scaling CLC agriculture, which is the core

purpose of the Council. These resource limitations may be particularly problematic in limiting "learn-by-doing" experiences for participants, as there is indication that participants in polycentric governance can increase the scope of their participation over time (Hileman and Bodin, 2019), after gaining experience. Recently, the Partnership has received new grant funding to support these cross-sector and cross-scale activities.

Accomplishments

Importantly, the main elements of the Partnership—as an implementation of the regional diversification strategy outlined above—have been formed, and certain key functional aspects of the network are coming into robust operation. First, new and highly-active elements of the Partnership have emerged, such as the Commercialization, Adoption, and Scaling group of the Forever Green Initiative, which was not part of the original design for the Partnership (Figure 1). That group and the crop-specific R&D teams have developed a set of pilot supply chains (Table 2), thus creating a set of variant SSCs, as is essential for the conscious cultural evolution process. For Kernza® perennial grain, these pilot supply chains have grown rapidly in the past several years, and now span thousands of acres, and many marketed products. Moreover, a parallel commercialization group for CLC crops has recently been initiated by the University of Wisconsin, demonstrating the replication that is key to cultural evolution. Second, the Partnership is achieving a growing reflexive capacity as a key tool for building an effective network, through the action-research methods that are being used by the Partnership's evaluators, and by members of the Learning and Experimentation Network, and the recent formation of an evaluation group drawn from the network's nodes, to assess functioning of the polycentric network as a whole. Finally, the Partnership been successful in attracting and integrating resources, which is a fundamental purpose of polycentric networks (Carlisle and Gruby, 2019). These include ongoing operational support from the Clean Water Council of the State of Minnesota, and from philanthropic sources. A large research grant was obtained in 2021 for a participatory action-research (Touboulic and Walker, 2016) project focused on the Partnership, seeking to characterize and evaluate the Partnership through the eyes of participants. In the 2022 Minnesota Legislative session, new state financial support was given to the Partnership, because of broad political support for the Partnership and continuous-living cover agriculture. Very few other legislative proposals attracted such broad support, which spanned two political parties that share power in the Legislature. This success shows the resource-provision potential of the Steering Council, as members of the Council invested considerable political capital in organizing the necessary breadth of support.

Evaluation and reflexivity in the Forever Green Partnership

The Partnership seeks to build a collective critical awareness of its performance and to improve over time. These aspirations are implemented by ongoing, multi-faceted, collective evaluation of all levels of the polycentric system, and of its function as a whole, in terms of key functions, outputs, and outcomes. This evaluation is based on participatory action research (Touboulic and Walker, 2016), implemented through developmental evaluation practices (Patton, 2010). These techniques serve to elucidate the experiences, perceptions, assumptions, and understandings of participants, and to create multiple deliberative settings for discussion of these, within nodes of the Partnership, and among nodes. Such wide-ranging and ongoing assessments are costly, requiring facilitation from skilled evaluators, and the investment of time, and cognitive and emotional engagement from all participants. In the face of the complexity of regional diversification, a particular focus of evaluation is supporting reflexivity, engaging participants in "questioning what we, and others, might be taking for granted—what is being said and not said—and examining the impact this has or might have." (Cunliffe, 2016). Such reflexive work is widely seen as essential to addressing complex challenges (McLoughlin et al., 2020), such as development of *"complex multi-level systems to cope with a complex, multi-level problem,"* to quote Ostrom (2010) once again. In late 2022, the major nodes of the Partnership (Steering Council, Learning and Experimentation Network, Organizing Group, and Strategy Group each had gatherings for the purpose of reviewing Ostrom's core design principles, with emphasis on articulation of each group's purpose, autonomy of group, internal trust and equity, and give/get.

Discussion and conclusion

Fundamentally, our project is concerned with achieving a crucial, broadly-supported sustainability transition in agriculture: diversification at regional scales. Our effort to develop a regional-scale diversification strategy is part of a growing body of theory and practice addressing sustainability transitions in agriculture (El Bilali, 2020; Scoones et al., 2020). In this body of work, the multi-level perspective (Geels, 2019) is an overarching theoretical framework (El Bilali, 2019), underlying most current approaches. The multi-level perspective posits that sustainability transitions result from the joint operation of 'top-down' pressures for change in dominant systems (e.g., broad societal demand for climate mitigation and adaptation in agriculture), and the availability of scalable alternatives to dominant systems that meet such demand, typically resulting from 'bottom-up' innovation. In practice, however, most sustainability transition efforts in agriculture focus narrowly on particular scales or sectors, rather than attempting to coordinate activities across sectors and scales (El Bilali, 2020). Undoubtedly, this reflects the difficulty and cost of organizing the joint operation of effort broadly across sectors and scales (Schlaili and Urmetzer, 2019). By organizing a cross-scale and cross-sector project, we aim to advance understanding of sustainability transitions in agriculture.

We also aim to advance understanding of the value of conscious cultural evolution in sustainability transitions such as regional diversification, inspired by drawing on recent advances in understanding of conscious cultural evolution and its facilitation (Brooks et al., 2018; Atkins et al., 2019). Sustainability transitions frameworks often seek to support adaptation and evolution of fundamental societal systems. However, these frameworks have not explicitly united with the developing theory and practice of facilitated and intentional cultural evolution as a sustainability strategy (Schlaili and Urmetzer, 2019). This union offers much: if evolution and adaptation of cultural elements such as food systems is the goal, then attention to the fundamental drivers of cultural evolution and

adaptation is warranted. Specifically, we propose that intentional design for facilitated cultural evolution can markedly increase the likelihood of progress in the adaptation and evolution that is essential for transition in agriculture. Our project is thus part of a larger stream of work exploring conscious cultural evolution as a novel approach to sustainability transitions (Brooks et al., 2018; Jones et al., 2020). As Brooks et al. note, cultural evolution is a unifying framework, clarifying the logic and underlying dynamics of strategies such as adaptive management and innovation systems.

Finally, we seek to contribute to broader use of principles and practices of responsible innovation and scaling (Kuzma, 2019; Schut et al., 2020; Stilgoe et al., 2020) in addressing sustainability transitions such as regional diversification. Of course, innovation and scaling are of the essence in agricultural diversification, and calls for their "responsibility" acknowledge that all scaled innovations produce a mix of outcomes, some beneficial, others not (Herrero et al., 2020). The foundations of such responsibility are anticipation, reflexivity, inclusion, and responsiveness (Stilgoe et al., 2020). The use of polycentric governance and conscious cultural evolution provide many opportunities to implement these principles in practice. Via the internal deliberations of these networks, and ongoing feedback between the top-down and bottom-up scales in polycentric networks, there is much scope for anticipating consequences of particular diversification pathways via inclusive and participatory processes, and for collective reflexivity and responsiveness to perceived shortcomings of diversification strategies.

For example, a key value of the Partnership is to avoid diversification strategies that perpetuate current social injustices in agriculture. By implementing this value in goal-setting and resource-provisioning activities, and collaborating with farmers from historically-marginalized groups to develop diversification pathways (i.e., SSCs) that respect this value, the Partnership is striving to practice responsible innovation and scaling with respect to this goal. This requires engagement of multiple interested and affected parties in a holistic discussion of ends and means of innovation and scaling, participatory and inclusive anticipation of outcomes of alternative diversification pathways, and on-going mutual learning and reflection on the innovation and scaling process and its outcomes. These processes—albeit challenging, deliberative, and unpredictable—are all inherent in the Partnership's polycentric and evolutionary approach. We argue that responsible innovation and scaling are essential to navigating sustainability transition projects in food and agriculture, and through implementation of the Partnership's strategy, we seek to build practical and conceptual approaches to taking such responsibility.

Data availability statement

The datasets presented in this article are not readily available because interview data were gathered under a confidentiality agreement. Summaries of interview data will be made available. Requests to access the datasets should be directed to jorda020@umn.edu.

Author contributions

NJ and DW developed the conceptual model. NJ, DW, KN, KM, TC, and CC contributed to the case study. KN, KM, and TC planned the evaluation research. KN and KM analyzed and interpreted interview data. All authors contributed to the article and approved the submitted version.

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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.

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