communications sustainability

A Nature Portfolio journal

Perspective

https://doi.org/10.1038/s44458-026-00081-3

Strengthening service and knowledge systems as pathways for addressing barriers to scaling agroecology

Check for updates

Muhammad Arshad [1] ✉, T. S. Amjath-Babu [2], Sreejith Aravindakshan [2], Timothy J. Krupnik [3] & Stefan Sieber [1,4]

Agroecology applies ecological and social principles to food and farming and is increasingly framed as a pathway to support human and environmental health. Yet its expansion beyond local settings remains limited. This Perspective synthesizes evidence from agriculture, sustainability science, public health, and policy research to examine why scaling efforts often stall. The analysis suggests that barriers arise less from technical limits and more from the incentives, institutions, and narratives shaping contemporary food systems, which continue to favor input intensive production and narrow performance metrics. We outline pathways through which progress may be supported within current governance and market structures. Strengthening shared knowledge systems and expanding specialized service provision can facilitate the adoption of agroecological practices. Aligning these efforts with biodiversity, climate, food safety, and public health goals could reinforce incentives to scale agroecology. Without such shifts, the contribution of agroecology to long term human and environmental well-being is likely to remain limited.

Agroecology as a convergent paradigm

The United Nations Food and Agriculture Organization (FAO) defines agroecology (AE) as a holistic and integrated approach that simultaneously applies ecological and social concepts and principles to the design and management of sustainable agriculture and food systems[1]. AE has gained recognition as a transformative paradigm capable of delivering sustainability gains with far-reaching socio-ecological benefits for human, animal, environmental and planetary health[2]. In this context, describing agroecology as "transformative" refers not merely to the adoption of alternative farming techniques, but to the reconfiguration of the institutional, economic, and knowledge systems that govern food production. While agroecological practices can be implemented at the farm level, their transformative potential lies in reshaping the incentive structures, evaluation metrics, and governance arrangements that underpin agricultural systems. Treating agroecology as a set of techniques risks its partial integration into existing models without addressing these structural constraints.

This transformative framing is increasingly articulated through established principles and transition pathways, including the High Level Panel of Experts (HLPE) agroecology principles and their operationalization across multiple levels of system change[3,4]. These frameworks explicitly link agroecological principles to progressive transition stages—from input substitution to systemic food system transformation—thereby providing a structured basis for understanding the dynamics and pathways of scaling[5,6]. Unlike other agri-food system paradigms (see Supplementary Table 1), AE requires rethinking and restructuring science, policy, and economic systems to create more equitable, health-enhancing, and environmentally regenerative agri-food systems. It addresses multiple sustainability challenges simultaneously, including resource constraints, ecosystem degradation, biodiversity loss, climate change, food insecurity, infectious and zoonotic diseases, and the persistence of poverty and malnutrition.

AE represents a low greenhouse gas (GHG) emissions pathway that supports biodiversity restoration both above and below ground, while enhancing soil carbon sequestration. As a paradigm, it embodies principles of strong sustainability by prioritizing the maintenance of natural capital, in contrast to the weak sustainability outcomes often associated with input-intensive agri-food systems. Its conceptual alignment with both One Health (OH) and Planetary Health (PH) is clear from a sustainability perspective: OH emphasizes the interdependence of human, animal, and environmental health in disease prevention, food safety, and ecosystem integrity, typically at local to regional scales, while PH focuses on the global stability of climate, biodiversity, and natural resource systems that underpin all life[7]. AE, OH, and PH share a systems perspective, recognizing that human well-being is

[1]Leibniz Centre for Agricultural Landscape Research (ZALF e. V), Müncheberg, Germany. [2]International Maize and Wheat Improvement Center (CIMMYT), Dhaka, Bangladesh. [3]Scaling for Impact Program , CGIAR System Organization, Dhaka, Bangladesh. [4]Department of Agricultural Economics, Faculty of Life Sciences, Humboldt Universität zu Berlin, Berlin, Germany. ✉e-mail: Muhammad.Arshad@zalf.de

inseparable from ecosystem health and the social structures that govern resource use. AE can therefore be understood as an operational pathway for advancing OH and PH objectives in agri-food systems.

Despite its potential as a transformative pathway for global agricultural systems, the scaling of AE remains constrained by prevailing governance arrangements, incentive structures, and power asymmetries that continue to stabilize dominant production models, even in the face of escalating environmental and public health risks. Political-economy and governance syntheses show that resistance to systemic change arises less from a lack of evidence or viable technical alternatives than from institutional lock-in, market concentration, and the privileging of monocrop, yield-centric productivity metrics that align with incumbent interests[8–10]. In this context, AE represents not merely an alternative set of agronomic practices, but a systemic challenge to the dominant narratives, evaluation regimes, incentive structures, research priorities, and policy logics that underpin contemporary food systems. These structural misalignments help explain the persistent gap between AE's well-documented social, ecological, and resilience benefits and its limited integration into mainstream policy and practice.

In this study, we adopt a critical–synthetic methodology to examine why AE transitions frequently stall and to identify pragmatic pathways for scaling within existing capitalist economic and policy structures. By integrating insights from interdisciplinary academic literature, implementation reports, and transdisciplinary frameworks, we develop a barrier typology spanning eight domains and delineate a solution space grounded in a service economy model that repurposes market, policy, and institutional mechanisms to support AE adoption at scale. By explicitly situating AE within OH and PH objectives, our analysis provides a framework for understanding and addressing the structural conditions required for systemic, scalable, and context-sensitive transitions toward more sustainable and regenerative food systems.

Methods

We adopted a critical–synthetic analytical approach to examine systemic barriers to scaling AE and to identify transition pathways that could be implemented within existing capitalist economic and policy structures. This approach is grounded in the tradition of critical interpretive synthesis, which integrates heterogeneous forms of evidence while explicitly interrogating underlying assumptions, power relations, and evaluative logics shaping complex socio-technical systems[11]. It is complemented by principles from integrative review methodology, which support the synthesis of empirical, conceptual, and policy-oriented sources[12], and transdisciplinary synthesis, which facilitates the integration of scientific and practice-based knowledge across governance and sectoral boundaries[13].

Rather than undertaking an exhaustive systematic review, we employed purposeful, theory-informed source selection to capture influential and analytically rich contributions from AE, sustainability science, food systems governance, public health and PH scholarship. Included sources comprised peer-reviewed interdisciplinary literature, authoritative policy and implementation reports, and established transdisciplinary frameworks relevant to AE, OH, PH, and food system transformation. Selection criteria prioritized conceptual relevance, explanatory depth, and demonstrated influence on policy or practice. Narrowly scoped agronomic trials lacking system-level implications, as well as context-specific case studies without broader analytical generalizability, were considered out of scope. Source identification was guided by citation tracing and expert knowledge of the field, rather than by predefined database queries, consistent with the objectives of critical interpretive synthesis.

The analysis proceeded through three iterative and interlinked stages, each informing subsequent synthesis. First, we undertook *paradigm-based problem framing*, mapping conceptual and practical tensions among dominant agri-food system paradigms and examining how AE is positioned politically, economically, and epistemologically within prevailing sustainability, health, and climate narratives. This step drew on foundational AE scholarship and high-impact synthesis literature to identify structural constraints rooted in incompatible economic logics, policy narratives, and governance architectures[1,14,15].

Second, we developed a *barrier typology* through iterative synthesis of interdisciplinary literature, implementation reports, and policy analyses. Recurring challenges were analytically clustered into eight interacting domains—conceptual, methodological, contextual, ecological, socio-economic, technological, philosophical, and communicative—capturing distinct but interconnected forms of ambiguity that constrain agroecological scaling. This typology provides the analytical basis for Fig. 1 and structures the Results and Discussions section.

Third, we delineated a *capitalist-compatible solution* space by synthesizing leverage points and enabling mechanisms identified across the reviewed literature. Rather than presupposing system-wide replacement of market-based food systems, this step examined how existing instruments—such as service-oriented business models, ecosystem service valuation, public procurement, impact investment, and regulatory standards (e.g., food safety and environmental standards)—could be repurposed to support knowledge- and service-intensive agroecological practices while advancing OH and PH objectives. Figure 2 visualizes this solution space by explicitly linking the identified barrier domains to corresponding institutional, market, and policy pathways.

Across all analytical stages, we triangulated conceptual, empirical, and policy insights to enhance analytical robustness and ensure relevance across diverse socio-economic and governance contexts. The findings presented in the Results and Discussions section correspond directly to the outputs of this three-stage critical–synthetic process, translating the synthesis into pragmatic, system-level insights for advancing agroecological scaling.

Results and discussions

Political narratives undermine agroecology

Our paradigm mapping identified political framing as a foundational barrier to AE scaling. Analysis of policy narratives revealed that AE is frequently positioned as "less modern", "socialist", or "incompatible with modern agriculture", reinforcing decision-maker preferences for yield maximization over ecosystem health and equity[14]. Comparative discourse review confirmed persistent policy mislabeling—conflating AE with organic or subsistence farming—despite documented scalability. Ambiguity is further compounded by the use of overlapping but narrower terms such as sustainable intensification and climate-smart agriculture[16]. This definitional instability, captured in our conceptual ambiguity domain (Fig. 1; Supplementary Table 2), constrains coherent policy support. AE's historical association with cooperative farming was also found to sustain perceptions of incompatibility with capitalist market logics, reinforcing resistance to mainstreaming[17].

The subsequent subsections elaborate on the domains of the barrier typology depicted in Fig. 2, which synthesizes the systemic, interlinked constraints to scaling AE identified through our analysis.

Institutional capacity, power asymmetries, and global disparity

Across the barrier typology, differences in institutional capacity emerge as a central condition shaping whether agroecological practices remain localized or become normalized within food systems. While AE is implemented at field and landscape scales, its scaling is governed by nationally embedded institutions that shape subsidies, regulatory enforcement, public procurement, extension systems, and risk-sharing mechanisms. Comparative syntheses show that uneven institutional coherence and enforcement capacity across regions generate divergent transition pathways, constraining the scalability and transferability of agroecological approaches in governance-constrained contexts[15].

These disparities are compounded by structural power asymmetries between territorially bounded public institutions and globally integrated corporate actors. Political-economy analyses of food systems show that multinational firms translate market power over inputs, value chains, and standards into political influence, reinforcing policy inertia and weakening the internalization of ecological and health externalities[18]. Rebalancing these

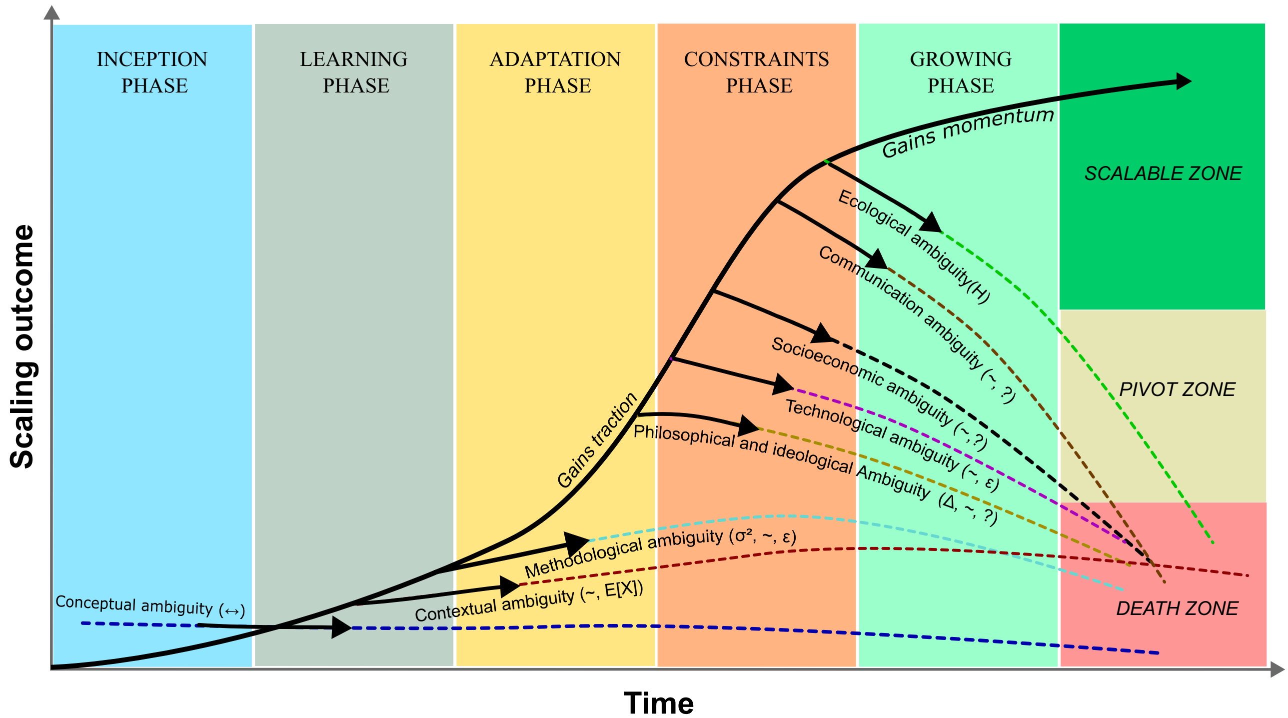

Fig. 1 | Phases of scaling agroecological innovations and associated ambiguities. The figure illustrates the ideal scaling trajectory of agroecological innovations across five phases: Inception, Learning, Adaptation, Constraints, and Growing. The scaling curve reflects increasing outcomes over time, leading to one of three zones: Scalable, Pivot, or Death. Eight types of ambiguity may divert scaling from the ideal path: Conceptual: Differing definitions of agroecology(↔). Methodological (σ^2, ~, ε): Inconsistent metrics and evaluation methods. Contextual (~, E[X]): Outcome variability due to local environmental and cultural factors. Ecological (H): Random ecological responses and system complexity. Socioeconomic (~,?): Uncertainty in economic viability and policy support. Technological (~, ε): Variable outcomes from agro-ecological practices and technologies. Philosophical (Δ, ~, ?): Conflicting values and ethical trade-offs. Communication (~, ?): Gaps in understanding across stakeholders. Dashed lines represent divergence due to unresolved ambiguities. The "critical ambiguity point" indicates where compounded uncertainties influence whether scaling advances or stalls.

dynamics does not require abandoning market-based food systems, but it does require strengthening public governance to compensate for institutional asymmetries. This includes redirecting subsidies toward ecosystem service provision, embedding agroecological criteria into procurement and trade frameworks, regulating market concentration, and creating efficient service-economy models for agroecology-based agriculture. Under current power configurations, farmers remain essential actors but cannot be the primary drivers of system-level agroecological scaling[15]. Farmer agency is conditioned by institutional design, risk distribution, the access and affordability of agroecological service provision, and market access, indicating that scaling depends less on individual decision-making than on reforming the institutional and market environments that govern incentives, knowledge flows, and value distribution across the food system toward a capitalist-compatible AE solution space.

The invisible hands of market are less able to drive agroecology

Economic structure analysis showed that AE's operational model—centered on labor, skills, knowledge, and locally producible biological inputs—conflicts with the product-oriented incentives of global agricultural markets. This divergence aligns with the socio-economic and technological ambiguity domains. Literature synthesis confirmed that biodiversity-based pest, weed, and fertility management under AE can raise aggregation and transaction costs, particularly in systems shifting away from monocropping[19]. Current mechanization infrastructure was found to be incompatible with intercropping systems. Certification and standardization barriers further restrict AE product market access, while monitoring frameworks to assess AE contributions to OH and PH are either lacking or still in early development.

An inherent tension runs through the proposed solution space: while AE fundamentally challenges productivist logics embedded in contemporary agri-food markets, the pathways identified here largely operate within existing market and policy architectures. This reflects a deliberate analytical choice rather than a normative claim that market-driven systems are sufficient to deliver agroecological transformation. Critical food systems scholarship shows that power asymmetries, capital concentration, and growth-oriented incentive structures systematically privilege yield-based productivity over ecological and health outcomes, limiting the depth of change achievable through market-compatible instruments alone[8,9].

Accordingly, the solution space should be understood as a set of enabling conditions that lower barriers and expand the feasibility of agroecological adoption under current political-economic constraints, while also offering steppingstones for deeper structural transformation. Making this tension explicit strengthens, rather than weakens, the analytical coherence of a pragmatic approach that seeks near-term leverage while recognizing the limits imposed by prevailing power relations.

Weaker evidence base at multiple scales hampers wider acceptance

Our synthesis of existing literature and implementation reports revealed a critical methodological gap: agroecological performance is rarely assessed through comprehensive, multi-scalar indicators. *Individual* crop yield remains the dominant success metric, with limited integration of system yield, biodiversity, soil, water and human health, and social equity outcomes[20]. Evidence from synthesis studies indicates that while agroecological systems may exhibit lower individual crop yields in some contexts, diversified systems ensure higher *system* yields, enhanced resilience, societal and planetary wellbeing[15]. Hence, from a OH and PH perspective, such yield trade-offs are therefore addressed at the food-system level rather than through plot-level yield maximization, by prioritizing risk reduction,

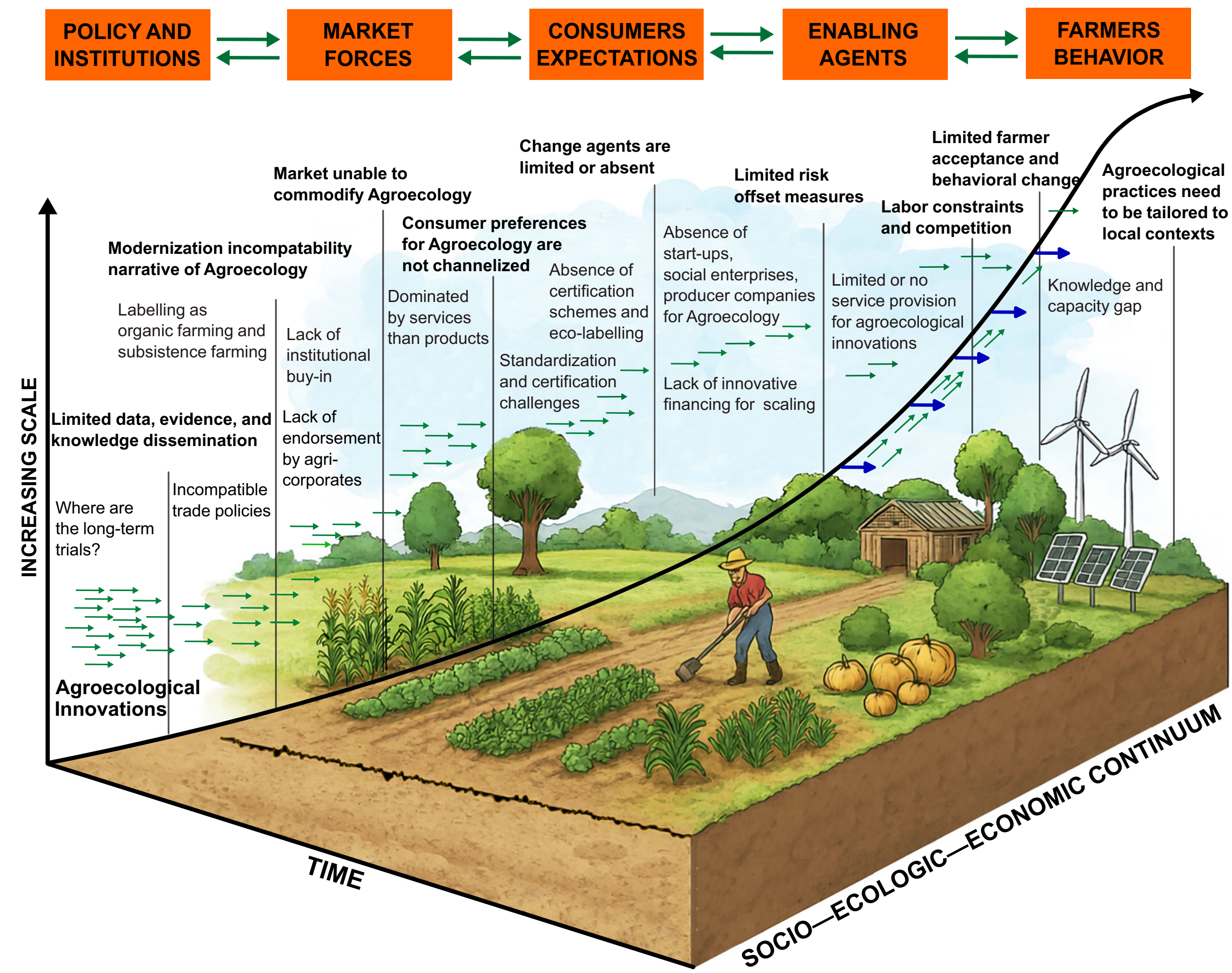

Fig. 2 | Barriers to scaling agroecological innovation for transformative change in agrifood systems. The figure synthesizes findings from our barrier typology (Step 2) and economic–policy framing analysis (Step 1), mapping how constraints intensify with both time and the complexity of AE practices. The x-axis represents the temporal evolution of AE adoption, and the y-axis reflects increasing agroecological complexity. Vertical panels denote key barrier domains identified in our analysis: limited data and knowledge dissemination, incompatibility with prevailing policy narratives, market and consumer disconnects, absence of enabling institutions and financing mechanisms, labor constraints and inadequate service provision, limited risk mitigation options, and low farmer acceptance with behavioral inertia. Green arrows indicate innovation trajectories where enabling conditions support scaling; blue arrows indicate points where scaling is hindered. The progression—from initial AE trials to diversified, service-intensive systems integrating crops, trees, and renewable energy—illustrates the systemic, interlinked nature of structural and functional barriers, highlighting the importance of coordinated, context-specific solutions.

functional diversification, and complementary production strategies that maintain food availability within ecological limits[21]. Also, the investment in private and public research needs to be reallocated to AE based production systems that enhance system level yield metric.

Scaling agroecological farming across the land base does not inherently require the parallel expansion of technologically intensive, non-land-based production to address food affordability or supply concerns. In some contexts, however, systems such as controlled-environment agriculture may play a complementary role, particularly under conditions of population growth, changing consumption patterns, or where biophysical constraints in marginal land environments limit the feasibility of certain forms of land-based production. Convergent synthesis evidence nevertheless indicates that many contemporary food security challenges arise less from constraints on food supply than from governance failures, unequal access, ecological degradation, and vulnerability to climate and input shocks[8,9]. Where technologically advanced non-land-based systems are pursued, their contribution appears context-specific and supplementary, rather than an alternative to scaling agroecological systems per se[22].

Consumers preference for agroecology is not channelized

Value chain mapping revealed an absence of robust mechanisms for channeling consumer preference towards AE products, corresponding to the communicative and market-related barriers in our typology. Current distribution systems rarely differentiate AE products, limiting informed consumer choice. Evidence from analogous eco-labeling schemes suggests that region-specific AE standards—highlighting biodiversity benefits, resource efficiency, or carbon sequestration—could activate latent demand. Incorporating such schemes into the solution space would align market signals with AE scaling objectives.

Knowledge-intensive practices demand tailoring

The contextual ambiguity domain was strongly evident in our synthesis: AE performance depends on tailoring practices to local ecological and socio-cultural conditions. Case analysis confirmed that success requires interventions adapted to specific challenges, e.g., water conservation in arid regions, biodiversity restoration in degraded landscapes. Pest and disease control strategies, including ecological pest management (EPM) and integrated pest management (IPM), must be region-specific to address local pest complexes effectively.

Labor constraints and ageing farmers limit adoption

Labor demand assessments from reviewed cases revealed consistently higher requirements relative to conventional systems, especially where diversification reduces mechanization compatibility. Demographic trend analysis showed that ageing farmer populations exacerbate these constraints, as AE's operational complexity demands both physical effort and adaptive management skills. Addressing this within the solution space involves AE-compatible mechanization and targeted youth engagement strategies.

Limited number or absence of change agents and champions

Institutional mapping identified a shortage of trained AE extension agents, service providers, and social enterprises, representing a governance-related barrier to scaling. Literature and program reviews indicated that capacity gaps in extension systems limit farmer access to AE-specific technical support[23]. Financing institutions remain largely absent as AE champions, restricting capital flow to AE-aligned ventures. The solution space emphasizes coordinated development of human capital, service networks, and financial sector engagement to address this deficit.

Limited farmer acceptance under institutional and market constraints

Much of the prevailing discourse places farmers' learning capacity, individual skill acquisition, access to capital, and risk-taking capacity at the center of agroecological transitions. While these factors are important, such framings risk overstating farmer agency while underplaying the structural conditions that shape risk exposure, resource access, and decision-making environments. We argue that reframing agroecological practices as services delivered by trained service providers can substantially reduce the burdens of skill acquisition, capital requirements, and risk embedded in the transition process. A service-oriented model redistributes skill requirements, capital investments, and operational risks away from individual producers and into specialized service ecosystems, thereby lowering transaction costs and smoothing transition pathways. Crucially, this approach renders agroecological transitions largely scale-neutral, enhancing their technical and economic viability across diverse farm sizes and production contexts, and positioning AE as a technically and economically viable alternative within market-oriented food systems.

Where AE-specific service provision models, risk mitigation mechanisms, and incentives are absent, and where markets fail to differentiate agroecological goods and services, farmers face structurally elevated risks that discourage transition. Under these conditions, limited farmer acceptance reflects constrained decision-making shaped by institutional and market structures rather than reluctance to engage with agroecological principles per se—a pattern consistently documented in institutional analyses of agroecological transitions[24,25].

Transition pathways

Building the agroecology solution space. Our analysis identified AE as a viable pathway for advancing OH and PH, provided it is embedded in a coordinated, multi-actor program involving governments, multilateral donors, private sector actors, service providers, social enterprises, and farmer organizations[26]. Unifying AE narratives and integrating them into national and global policy frameworks emerged as a priority. Mapping of financial instruments highlighted opportunities to repurpose revolving funds, green bonds, climate finance, impact investments, and community-based funding towards AE. Carbon credit schemes incentivizing agroforestry, reduced tillage, and soil carbon storage could generate new revenue streams. Region-specific eco-labeling—supported by subsidies or preferential market access—can further mobilize market forces. Bridging yield gaps linked to degraded natural, social, and human capital requires integrating AE into national food security strategies[16].

Decentralized demonstration hubs, open-access knowledge platforms, and co-innovation through farmer-led research were identified as essential for evidence generation and technology transfer[27–29]. Several synthesis studies identify a potential role for emerging participatory and digital tools, including decision-support systems data analytics and Living Labs, in supporting knowledge integration and coordination in agroecological systems, while also emphasizing that evidence of their contribution to scalability remains limited and highly context-dependent[30–34]. European initiative named the Agroecology Partnership illustrates how multi-stakeholder Living Labs and research infrastructures are being mobilized to accelerate agroecological transitions at scale by supporting resilient, sustainable food systems that address climate change, biodiversity loss, and environmental health[35,36]. Such institutional efforts align with OH and PH by integrating ecological, social, and health considerations into coordinated policies and practice across governance scales.

Service provision models for agroecological practices

Our synthesis identified five critical service provision domains essential for scaling AE:

- Biocontrol of pests: Requires technical advisory services for managing predator–prey dynamics and localized services for the deployment and monitoring of biocontrol agents[37].
- Nutrient cycling and soil health: Involves localized services for soil testing, soil amendments, beneficial organisms, composting, and rotation planning to replace or reduce synthetic inputs while enhancing soil carbon sequestration[38].
- Water management: Requires climate-specific advisory systems for rainwater harvesting, mulching, and soil moisture monitoring to ensure sustainable water management at both individual farm and landscape scales[39].
- Pollination services: Demands habitat creation, increases in pollinator populations, wildflower border management, and pesticide reduction to sustain pollination functions[40].
- Agroforestry and habitat management: Relies on expert guidance for species selection, tree–crop compatibility, and pruning practices that ensure both ecological functionality, economic and business viability[41].

Together, these domains demonstrate that agroecological scaling depends on ongoing technical support networks, localized expertise, and service-based delivery models, rather than one-time interventions or input substitution alone.

Developing knowledge brokering models for agroecology

Knowledge transacting models emerged as a cornerstone for AE scaling, reflecting the FAO's emphasis on co-creation and sharing of knowledge[1]. We found that localized hubs—linking farmers, researchers, service providers, and technical advisors—can facilitate adaptive learning and context-specific innovation[42]. Integration of indigenous practices, scientific research, and practical experience within these hubs strengthens resilience and transferability. In the future, aggregated learning from such hubs could train AI models to reduce operational costs and improve real-time decision support.

Policy reform and anti-greenwashing measures

Our review of governance structures indicates that AE's transformative potential is often undermined by policy frameworks that continue to favor input-based, high-throughput monocropping systems[43]. The risk of politically motivated greenwashing—where AE terminology is adopted without adherence to its core principles—emerged as a threat to meaningful transition[44]. Safeguarding AE therefore requires policy reforms that prioritize credible service provision, robust knowledge systems, and ecosystem resilience, while ensuring that profit-driven interests do not dilute AE's foundational values or rebrand conventional practices under an agroecological label.

Building resilient market models for service-based economies

Economic analyses underscore the need for circular and service-based economy models that generate value from ecosystem services, diversified production systems, diverse service requirements, local market linkages, and employment generation[1]. In this context, the concept of "managed connectivity"—which strategically links local food systems to broader regional and global networks—emerges as a viable pathway for scaling AE while retaining local value capture[45]. Investments in infrastructure for localized service provision models, supported by digital tools, aggregation mechanisms, and certification systems, can stabilize farmer incomes and reduce vulnerability to volatility in global commodity markets.

Cultivating public engagement and food literacy

The final dimension of the solution space emphasizes public engagement. Analysis confirmed that low food systems literacy constrains demand for AE products[45]. Coordinated educational initiatives, participatory certification, and transparent supply chains can build consumer trust and align purchasing decisions with OH and PH values[46]. Policies supporting farm-to-table models, local food education, and community-based food systems can shift consumer culture towards valuing AE's ecological and social benefits.

Conclusions

Towards systemic and scalable agroecological transitions

Our critical–synthetic analysis demonstrates that scaling AE within existing capitalist economic and policy structures is both feasible and necessary for advancing OH and PH. The barrier typology developed in this perspective shows that agroecological transitions are constrained by interlinked political, market, evidentiary, consumer, knowledge, labor, institutional, and behavioral domains. These constraints extend beyond technical or informational limitations, reflecting entrenched incentive structures and power asymmetries that continue to privilege individual crop yield maximization and short-term profitability over ecological integrity and health outcomes.

Addressing these barriers requires coordinated interventions that reorient markets toward service- and knowledge-based provision models, supported by the institutional embedding of AE within enabling policy, financial, technological, and change-agent networks. The solution space articulated here identifies context-sensitive pathways that do not presuppose system-wide replacement, but instead repurpose existing instruments—including eco-labeling, carbon credits, impact investment, decentralized demonstration hubs, and knowledge-brokering platforms linked to agroecological service provision ecosystems and their enabling environments—to lower barriers to scaling under current political–economic conditions. Translating this synthesis into action requires prioritizing a set of near-term, system-level interventions. First, policy frameworks must shift from input- and yield-based support toward rewarding ecosystem services and multifunctional outcomes, including soil health, biodiversity, and public health co-benefits. Second, the development of agroecological service provision ecosystems—comprising technical advisory networks, biological input systems, and decentralized knowledge platforms—should be supported to reduce transition risks and enable scale-neutral implementation. Third, market and financial mechanisms, including public procurement, eco-labeling, and blended finance instruments, need to be reoriented to recognize and valorize agroecological performance beyond commodity yield. Finally, coordinated investment in transdisciplinary research and monitoring systems is required to operationalize multiscalar performance metrics aligned with OH and PH objectives.

Taken together, this perspective situates AE not as a marginal or farmer-burdened alternative, but as a service-dominant economic model capable of operating within prevailing political–economic systems while addressing the limitations of goods-dominant agricultural paradigms. The analysis indicates that progress toward OH and PH outcomes depends less on the diffusion of individual practices than on the alignment of market signals, institutional incentives, and governance arrangements that structure decision-making across food systems. Where such alignment is absent, agroecological transitions are likely to remain partial and uneven, constraining their capacity to deliver sustained ecological integrity, public health benefits, and long-term food system resilience in support of OH and PH.

Data availability

No new datasets were generated or analyzed for this study. This perspective is based on a critical–synthetic analysis of existing, publicly available literature, including peer-reviewed journal articles, institutional reports, and policy documents. All sources used are cited in the reference list.

Received: 21 October 2025; Accepted: 22 April 2026;
Published online: 14 May 2026

References

1. Food and Agriculture Organization of the United Nations (FAO). Agroecology Knowledge Hub. FAO. https://www.fao.org/agroecology/en/ (2023).
2. Kerr, R. B. et al. Agroecology as a transformative approach to tackle climatic, food and ecosystemic crises. *Curr. Opin. Environ. Sustain* **62**, 101275 (2023).
3. High Level Panel of Experts on Food Security and Nutrition (HLPE). Agroecological and other innovative approaches for sustainable agriculture and food systems that enhance food security and nutrition. FAO, Rome. http://www.fao.org/cfs/cfs-hlpe/en/ (2019).
4. Wezel, A. et al. Agroecological principles and elements and their implications for transitioning to sustainable food systems. *Agron. Sustain Dev.* **40**, 40 (2020).
5. Gliessman, S. R. Transforming food systems with agroecology. *Agroecol. Sustain Food Syst.* **40**, 187–189 (2016).
6. Moeller, N. I. et al. Measuring agroecology: introducing a methodological framework. *Elem. Sci. Anthropocene* **11**, 00042 (2023).
7. Whitmee, S. et al. Safeguarding human health in the Anthropocene epoch: report of The Rockefeller Foundation–Lancet Commission on planetary health. *Lancet* **386**, 1973–2028 (2015).
8. Leeuwis, C., Boogaard, B. K. & Atta-Krah, K. How food systems change (or not): governance implications for system transformation processes. *Food Secur.* **13**, 761–780 (2021).
9. Béné, C. Why the Great Food Transformation may not happen—a deep-dive into our food systems' political economy, controversies and politics of evidence. *World Dev.* **154**, 105881 (2022).
10. Moallemi, E. A. et al. Resistance to sustainability transformations and ways to overcome it. *SSRN* https://doi.org/10.2139/ssrn.5547898 (2025).
11. Dixon-Woods, M. et al. Conducting a critical interpretive synthesis of the literature on access to healthcare by vulnerable groups. *BMC Med. Res. Methodol.* **6**, 35 (2006).
12. Whittemore, R. & Knafl, K. The integrative review: updated methodology. *J. Adv. Nurs.* **52**, 546–553 (2005).
13. Lang, D. J. et al. Transdisciplinary research in sustainability science: practice, principles and challenges. *Sustain Sci.* **7**, 25–43 (2012).
14. Altieri, M. A. & Nicholls, C. I. Agroecology and the reconstruction of a post-COVID-19 agriculture. *J. Peasant Stud.* **47**, 881–898 (2020).
15. Ewert, F., Baatz, R. & Finger, R. Agroecology for a sustainable agriculture and food system: from local solutions to large-scale adoption. *Annu. Rev. Resour. Econ.* **15**, 351–381 (2023).
16. Leakey, R. R. B. A multifunctional future for tropical agriculture: scoring multiple sustainable development goals simultaneously? *Agricult. Dev.* **47**, 22–46 (Tropical Agriculture Association, 2023/24).
17. Altieri, M. A. & Toledo, V. M. The agroecological revolution in Latin America: rescuing nature, ensuring food sovereignty and empowering peasants. *J. Peasant Stud.* **38**, 587–612 (2011).
18. Baker, P. et al. Ultra-processed foods and the nutrition transition: global, regional and national trends, food systems transformations and political economy drivers. *Obes. Rev.* **21**, e13126 (2020).

19. Sietz, D., Klimek, S. & Dauber, J. Tailored pathways toward revived farmland biodiversity can inspire agroecological action and policy to transform agriculture. *Commun. Earth Environ.* **3**, 211 (2022).
20. Leakey, R. R. B. The role of trees in agroecology and sustainable agriculture in the tropics. *Annu. Rev. Phytopathol.* **52**, 113–133 (2014).
21. Tamburini, G. et al. Agricultural diversification promotes multiple ecosystem services without compromising yield. *Sci. Adv.* **6**, eaba1715 (2020).
22. Ng, S., Hinrichsen, O. & Viswanathan, S. Contextual conditions define maximum energy-use threshold in low-carbon controlled environment agriculture for agri-food transformation. *Nat. Commun.* **17**, 880 (2026).
23. Degrande, A., Tchoundjeu, Z., Kwidja, A. & Fouepé, G. F. Rural resource centres: a community approach to extension. In *GFRAS Good Practice Notes for Extension and Advisory Services, Note* 10 (GFRAS, Lindau, 2015).
24. Giraldo, O. F. & Rosset, P. M. Agroecology as a territory in dispute: between institutionality and social movements. *J. Peasant Stud.* **45**, 545–564 (2018).
25. Dessein, J. Beyond institutional bricolage: an 'intertwining approach' to understanding the transition towards agroecology in Peru. *Ecol. Econ.* **187**, 107091 (2021).
26. Ong, T. W. et al. Momentum for agroecology in the USA. *Nat. Food* **5**, 539–541 (2024).
27. Brock, S. et al. Knowledge democratization approaches for food systems transformation. *Nat. Food* **5**, 342–345 (2024).
28. Warner, B. P., Walsh-Dilley, M., Nelson-Nuñez, J. & Duvall, C. S. Rural transformation in Latin America's changing climate. *J. Lat. Am. Geogr.* **19**, 10–25 (2020).
29. Leakey, R. R. B. Agroforestry—participatory domestication of trees. In *Encyclopedia of Agriculture and Food Systems*, Vol. 1, 253–269 (ed. van Alfen, N.) (Elsevier, San Diego, 2014).
30. Yousefi, M., Matzdorf, B. & Ewert, F. Research frameworks in agricultural living labs: a systematic review and comparative analysis. *Agric. Syst.* **233**, 104629 (2026).
31. Stone, T. F. et al. Agroecology living labs to transform food systems: a critical review at the science–policy–society nexus in Europe. *Agroecol. Sustain. Food Syst.* 1–42 (2025). Online ahead of print.
32. Bonatti, M. et al. Agricultural living labs: bridging theory and practice through transformative learning. *J. Agric. Educ. Ext.* 1–23 (2026).
33. Whitney, C., Biber-Freudenberger, L. & Luedeling, E. Decision analytical methods for assessing the efficacy of agroecology interventions. *CABI Agric. Biosci.* **4**, 11 (2023).
34. Rotz, S. et al. The politics of digital agricultural technologies: a preliminary review. *Socio. Ruralis* **59**, 203–229 (2019).
35. European Commission. European partnership on accelerating farming systems transition: agroecology living labs and research infrastructures. *CORDIS Fact Sheet, Grant agreement ID* 101132349 (2024). https://doi.org/10.3030/101132349
36. Agroecology Partnership. *About the Agroecology Partnership*. https://www.agroecologypartnership.eu/en/about/ (2024).
37. Altieri, M. A. & Nicholls, C. I. *Biodiversity and Pest Management in Agroecosystems* 2nd edn (CRC Press, 2004).
38. Drinkwater, L. E., Wagoner, P. & Sarrantonio, M. Legume-based cropping systems have reduced carbon and nitrogen losses. *Nature* **396**, 262–265 (1998).
39. Pretty, J. N. et al. Resource-conserving agriculture increases yields in developing countries. *Environ. Sci. Technol.* **40**, 1114–1119 (2006).
40. Kremen, C., Williams, N. M. & Thorp, R. W. Crop pollination from native bees at risk from agricultural intensification. *Proc. Natl. Acad. Sci. USA* **104**, 19601–19606 (2007).
41. Mbow, C. et al. Achieving mitigation and adaptation to climate change through sustainable agroforestry practices in Africa. *Curr. Opin. Environ. Sustain* **6**, 8–14 (2014).
42. Pretty, J. Regenerative agriculture and redesign for sustainability. In *Biological Approaches to Regenerative Soil Systems* 13–24 (CRC Press, 2023).
43. Tittonell, P. et al. Regenerative agriculture—agroecology without politics? *Front Sustain Food Syst.* **6**, 844261 (2022).
44. De Schutter, O. Agroecology and the right to food. *Report presented at the 16th Session of the United Nations Human Rights Council* (2010).
45. Wood, A. et al. Reframing the local–global food systems debate through a resilience lens. *Nat. Food* **4**, 22–29 (2023).
46. McGreevy, S. R. et al. Sustainable agrifood systems for a post-growth world. *Nat. Sustain* **5**, 1011–1017 (2022).

Acknowledgements

Muhammad Arshad acknowledges support from the Leibniz Center for Agricultural Landscape Research (ZALF e.V.), Müncheberg, Germany, and thanks Ms. Karin Stahl, manager of the Development-oriented International Agricultural Research (DIA) working group, for administrative and logistical support throughout this work. T.S. Amjath-Babu, Sreejith Aravindakshan and Timothy J. Krupnik acknowledge support from the CGIAR Scaling for Impact (S4I) Program (https://www.cgiar.org/cgiar-research-portfolio-2025-2030/scaling-impact) and the funders contributing to the CGIAR Trust Fund (https://www.cgiar.org/funders/).

Author contributions

Muhammad Arshad conceived the study and wrote the original draft. Muhammad Arshad, T.S Amjath-Babu and Sreejith Aravindakshan conceptualized different components of the study and contributed to the methods, results, and overall presentation of the manuscript. Timothy J. Krupnik and Stefan Sieber provided critical comments and detailed revisions. All authors contributed to revising the manuscript and approved the final version.

Funding

Open Access funding enabled and organized by Projekt DEAL.

Competing interests

The authors declare no competing interests.

Additional information

Supplementary information The online version contains supplementary material available at https://doi.org/10.1038/s44458-026-00081-3.

Correspondence and requests for materials should be addressed to Muhammad Arshad.

Peer review information *Communications Sustainability* thanks Erin Sherry, Oriana Gava and the other, anonymous, reviewer(s) for their contribution to the peer review of this work. Primary Handling Editors: Chenchen Ren and Yann Benetreau. A peer review file is available.