Agroecology & climate change rapid evidence review

PERFORMANCE OF AGROECOLOGICAL APPROACHES IN LOW- AND MIDDLE- INCOME COUNTRIES

April 2021

Sieglinde Snapp
Yodit Kebede
Eva Wollenberg
Kyle M. Dittmer
Sarah Brickman
Cecelia Egler
Sadie Shelton

CGIAR
RESEARCH PROGRAM ON
Climate Change, Agriculture and Food Security
CCAFS

Foreign, Commonwealth & Development Office

AUTHORS

Sieglinde SNAPP, Michigan State University, USA

Yodit KEBEDE, French National Research Institute for Sustainable Development (IRD) and The Alliance of Bioversity International and International Center for Tropical Agriculture (CIAT)

Lini WOLLENBERG, CGIAR Research Program on Climate Change, Agriculture and Food Security and University of Vermont – Corresponding author - lini.wollenberg@uvm.edu

Kyle M. DITTMER, CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) and The Alliance of Bioversity International and The International Center for Tropical Agriculture (CIAT)

Sarah BRICKMAN, University of Vermont

Cecelia EGLER, University of Vermont

Sadie SHELTON, CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) and University of Vermont

CITATION

Snapp S, Kebede Y, Wollenberg E, Dittmer KM, Brickman S, Egler C, Shelton S. 2021. Agroecology and climate change rapid evidence review: Performance of agroecological approaches in low- and middle- income countries. Wageningen, the Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

COVER PHOTO: Farmer in Jawhar, Maharastra, India. Photo credit: Neil Palmer (CIAT/CCAFS).

CONTACT INFORMATION

CCAFS Program Management Unit
Wageningen University & Research
Lumen building
Droevendaalsesteeg 3a
6708 PB Wageningen
THE NETHERLANDS
Email: ccafs@cgiar.org

ACKNOWLEDGEMENTS

We would like to thank Ajay Vir Jakhar, Alan Tollervey, Alesha Miller, Anna De Palma, Barbara Gemmil-Herren, Batamaka Somé, Boru Douthwaite, Bruce Campbell, Christian Huyge, Christian Witt, Christophe Larose, Daniel France van Gilst, Dhanush Dinesh, Diana Salvemini, Emily Weeks, Fabio Leippert, Giles Henley, Guy Faure, Howard Standen, James Birch, Jean-Francois Soussana, Jerry Glover, Joanna Francis, Julian Gonzalez, Mercedes Bustamante, Michael Farrelly, Michael Okoti, Nick Remple, Noel Gurwick, Rachel Lambert, Rikin Gandhi, Stephanie Heiland, Tom Tomich, Ueli Mauderli, Vijay Kumar, Wijnand Van Ijssel, Ken Giller, Confidence Duku and Annemarie Groot.

This work was funded by the New Venture Fund and the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), which is carried out with support from the CGIAR Trust Fund and through bilateral funding agreements. For details please visit https://ccafs.cgiar.org/donors. The views expressed in this document cannot be taken to reflect the official opinions of these organisations.

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ACRONYMS AND ABBREVIATIONS

AE	Agroecology/agroecological
AFSA	Alliance for Food Sovereignty in Africa
AgR4D	Agriculture research for development
APCNF	Andhra Pradesh Community-managed Natural Farming
BMGF	Bill and Melinda Gates Foundation
C	Carbon
CA	Conservation agriculture
CCAFS	CGIAR Research Program on Climate Change, Agriculture and Food Security
CH_4	Methane
CIRAD	Centre de Coopération Internationale en Recherche Agronomique pour le Développement (French Agricultural Research Center)
CO_2	Carbon dioxide
COMDEKS	Community Development and Knowledge Management for the Satoyama Initiative
CoP	Communities of Practice
CRA	Climate-resilient agriculture
CRP	Community Resource Persons
CSA	Climate-smart agriculture
DG DEVCO	Directorate-General for International Cooperation and Development
EU	European Union
FAIR Sahel	Fostering an Agroecological Intensification to improve farmers' Resilience in Sahel
FAO	Food and Agriculture Organization of the United Nations
FCDO	Foreign, Commonwealth and Development Office
FTA	CGIAR Programme on Forests, Trees and Agroforestry
GCF	Global Climate Fund
GEF	Global Environment Facility
GHG	Greenhouse gas emissions
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
IFAD	International Fund for Agricultural Development
IIRR	International Institute for Rural Reconstruction
INRAE	National Research Institute for Agriculture, Food and Environment
IPM	Integrated pest management
KALRO	Kenya Agricultural and Livestock Research Organization
LMIC	Low-and middle-income country
NDC	Nationally determined contributions
NGO	Non-governmental organization
NH_3	Ammonia
NORAD	Norwegian Agency for Development Cooperation
N_2O	Nitrous oxide
SDC	Swiss Agency for Development and Cooperation
SDG	Sustainable Development Goals
SI	Sustainable intensification
TAPE	Tool for Agroecology Performance Evaluation
TI	Title
TPP	Transformative Partnership Platform
TS	Topic
UNDP-GEF	United Nations Development Programme-Global Environment Facility
UNFCCC	United National Framework Convention on Climate Change
USA	United States of America
USAID	United States Agency for International Development
WFP	World Food Programme
WoS	Web of Science

Executive summary

Agroecology is increasingly seen as being able, or even necessary, to transform food systems (HLPE 2019). The Foreign, Commonwealth and Development Office (FCDO) and the CGIAR Research Programme on Climate Change, Agriculture and Food Security (CCAFS) commissioned this rapid evidence-based review to assess the quality and strength of evidence regarding (i) the impact of agroecological approaches on climate change mitigation and adaptation in low- and middle-income countries (LMICs) and (ii) the programming approaches and conditions supporting large-scale transitions to agroecology and transitions. The review also aims to identify knowledge gaps critical to understand and inform future public and private investment in research, development, and deployment of agroecological approaches. The focus here is on the science of agroecology at the field and landscape level, not on social movement, value chain or business aspects. We use the Food and Agriculture Organization of the United Nations (FAO) 10 elements of agroecology with the Gliessman (2016) framework to identify agroecology practices (transition level 2) and agroecology systems (transition level 3).

To assess evidence related to agroecology's climate change outcomes we conducted a systematic literature review of i) synthesis papers and ii) primary empirical studies related to nutrient and pest and disease management. For the latter we documented the presence of evidence for climate change outcome indicators, but not the magnitude or direction of the change. We also conducted semi-structured interviews with representatives from 12 organisations supporting or implementing on-the-ground agricultural development programmes to better understand the feasibility of scaling out agroecology.

How much evidence is there?

We identified 18 synthesis papers of high scientific quality relevant to the impacts of agroecology on climate change adaptation, mitigation or on the scaling of agroecology in the tropics or LMICs, representing over 10,212 studies. Nine papers presented findings based on 50% or more articles with data from LMICs, including four based 100% on LMICs data. Next, we conducted a systematic literature review to identify primary evidence for agroecological approaches related to nutrient management and climate change outcomes (15,674 articles) and for agroecological approaches related to pests and diseases and climate change outcomes (5,498 articles). From there, we identified a subset of 138 papers that also considered some aspect of scaling or adoption, and were conducted in the Global South. Of these papers, 115 reported on indicators relevant to climate change adaptation and mitigation. About one-third of these papers (48 papers) provided empirical evidence related to scaling agroecological approaches.

The availability of evidence for impacts on climate change outcomes is mixed. Substantial evidence exists for the impacts of practices and systems aligned with agroecology (e.g., farm diversification, agroforestry and organic agriculture) on indicators of climate change adaptation. Evidence for impacts on mitigation is modest, except for enhanced carbon (C) sequestration in soil and biomass associated with agroecological approaches, notably for agroforestry. The modest number of studies conducted in the Global South, and the short-term, field- and farm-scale nature of most studies highlights the need for more studies in the tropics and LMICs, including high-quality, long-term, research on farms and at landscape scales that compares agroecology against alternatives. Studies on climate change mitigation are particularly needed.

What does the evidence tell us?

CLIMATE CHANGE OUTCOMES OF AGROECOLOGY

The agroecological approach with the strongest body of evidence for impacts on climate change adaptation was farm diversification (strong evidence and high agreement). This included positive impacts of diversification on pollination, pest control, nutrient cycling, water regulation and soil fertility.

The agroecological approach with the strongest body of evidence for impacts on climate change mitigation was tropical agroforestry, which had associated sequestration of carbon in biomass and soil. In general, agroecology impacts on climate change mitigation were primarily substantial carbon sequestration benefits (medium evidence, high agreement). There was also evidence – primarily from the Global North – that mitigation of nitrous oxide (N_2O) is often associated with organic farming and ecological management of nutrients (medium evidence, medium agreement). However, a large data gap was found for agricultural greenhouse gas emissions, with almost no evidence from the Global South. There were also evidence gaps for agroecology approaches involving livestock integration, landscape-scale redesign and for multi-scalar analysis.

ADAPTIVE CAPACITY AND LOCAL ENGAGEMENT FOR IMPROVING CLIMATE CHANGE OUTCOMES

Agroecological approaches related to co-creation and sharing of knowledge support climate change adaptive capacity (strong evidence, medium agreement). Multiple lines of evidence show that engaging with local knowledge through participatory and education approaches are effective at adapting technologies to local contexts and thereby delivering improved climate change adaptation and mitigation.

AGROECOLOGICAL TRANSITIONS FOR LARGE-SCALE IMPACTS

Farmer co-creation and exchange of knowledge, community-based, participatory engagement, localised solutions and social organising were common components of field programmes for bringing agroecology to scale. Scaling agroecology systems, as opposed to practices, made more use of participatory and farmer-to-farmer processes and the role of policy, according to the literature. Scaling also relied on market and policy measures that privileged local production. The inherent complexity and knowledge intensity of agroecology, sometimes incurred higher cost and more time compared to conventional agriculture, but this also enabled effectiveness and sustained benefits. The literature review of scaling agroecological approaches for nutrient management and pest and disease management showed many of the same interventions, enabling conditions and barriers as those observed for conventional agriculture.

Recommendations

We recommend an outcome-based approach to assessing performance of agricultural development. This is to avoid contestation around what is encompassed by a specific label for an agricultural alternative, and instead assess performance in terms of environmental services and climate change response. A number of frameworks exist that can inform this work (Wezel et al. 2020, Kapgen and Roudart 2020, Grabowski et al. 2018) and can be used to measure performance. These include the Tools for Agroecological Performance Evaluation (TAPE by FAO), Sustainable Intensification Assessment Framework (USAID-supported). Labels like agroecology can still be expedient for communication; the point is to spend less time debating what is agroecology.

Based on the strength of the evidence, we can recommend investments in agricultural diversification, local adaptation, and in pathways to scaling both. Programme implementation experts indicated that promoting agricultural diversity can be a scalable intervention, and that it is often prioritised in programmes supporting agroecology. At the same time, trends are in the opposite direction, with widespread simplification of farms and cropping systems. Top down, single solutions are often promoted in agriculture development; thus, diversification and adaptation may require special attention and investment.

The lack of data on response to extreme climate events and on greenhouse gas emissions from tropical agriculture is a matter of great concern. We call for investment to fill these knowledge gaps, including comparative (alternatives versus conventional) and holistic (social, financial, and environmental as well as agronomic) assessment of climate change mitigation effectiveness and response to weather extremes that threaten future food security. There is urgent need for research on these topics in agricultural systems of LMICs, and by scientists and institutions from the Global South to build capacity in these regions.

Investment is also required in analysis of performance across multiple dimensions and trade-offs for approaches aligned with agroecology relative to other agriculture development approaches, at plot and farm levels, as well as beyond. This should include cost-effectiveness. Valuation of a range of agroecological benefits can be hard to quantify (e.g., environmental and social benefits), and economics often reflect current policy context and short time horizons.

Therefore, evidence-based priority investments include:

- The diversification of products and practices at field, farm and landscape level.
- Processes that support farmer innovation, co-learning and adaptation of innovations to local contexts.
- Move beyond contestation regarding what is agroecology and alternative labels. Focus instead on assessing outcomes of agricultural development approaches, building on indicator frameworks newly available (TAPE, Sustainable Intensification (SI) Assessment Framework).

To address urgent knowledge gaps, research priorities include:

- Barriers and how to enhance opportunities for scaling out of diversification and local adaptation processes, across landscapes and regions, through multiple agricultural development pathways that include agroecology.
- Research in tropical and low-income countries on climate change adaptation to extreme weather and quantitative assessment of mitigation outcomes at multiple scales.
- Scientific documentation of the effectiveness of agroecological approaches compared to alternatives, including performance in terms of environmental, social and cost-effectiveness, and direction of impact on climate change outcomes.
- South-South research collaboration.

1. Introduction

Background and objectives

It is widely recognised that transformation of food systems is needed to achieve food and nutrition security globally in the context of a changing climate (Steiner et al. 2020). Agroecology is increasingly seen as one pathway to transform food systems by applying ecological principles to ensure the sustainable use of natural resources and provision of ecosystem services (HLPE 2019).

In November 2020, FCDO and CCAFS commissioned this rapid evidence review to increase knowledge of impact of agroecological agricultural practices on climate change adaptation and mitigation. The goal of the study is to conduct a robust, but rapid synthesis of the quality and strength of evidence of the impact of agroecological approaches on climate change mitigation and adaptation in low- and middle-income countries (LMICs). Evidence for achieving agroecological impacts at large scales is an emphasis. The review also aims to identify knowledge gaps critical to understand and inform future public and private investment in research, development and deployment of agroecological approaches.

The objectives of the review are to synthesise the evidence and knowledge gaps for:

1. the impacts of agroecological approaches on climate change adaptation and mitigation in major agricultural systems in LMICs, and
2. the programming approaches and conditions supporting large-scale implementation of agroecological approaches and transitions.

We reviewed the evidence for climate change adaptation and mitigation impacts using a combination of systematic scientific review papers and primary evidence from scientific papers; we also conducted interviews to better understand the conditions supporting scaling up of agroecology (see Methods). Given the time constraints of a rapid evidence review we focused on agroecology approaches at field, farm and landscape scales, thus on practices and farm systems, not social movements, value chain or business aspects. Given these caveats, we synthesised key findings and conclude with recommendations to inform public investments in agricultural development.

Scope of agroecology and link to climate change adaptation and mitigation

Agroecology can refer to a (1) social movement (Altieri and Toledo 2011, Anderson et al. 2019), (2) set of principles (Wezel et al. 2020), or (3) scientific discipline (Tomich et al. 2011) (Andrieu and Kebede 2020). The role of agroecology in development is often divergent and contested, depending on these different perspectives (Bellword-Howard and Ripoll 2020). Our focus is on a scientific description of agroecology at field, farm and landscape levels, given our purpose of reviewing the evidence for impacts on climate change adaptation and mitigation (Tomich et al. 2011). We use the abbreviation AE to refer to agroecology or agroecological approaches in this document. Climate outcomes refer here to climate change adaptation and mitigation resulting from agricultural practices.

While there is no a priori, clearly defined single set of agroecological approaches to use for this analysis, we considered approaches as more agroecological to the extent they made use of ecological processes, supported increasing autonomy from external inputs, and enabled whole system change, rather than focusing on changing single practices (Sinclair et al. 2019, Leippert et al. 2020). We drew on the Food and Agriculture Organization of the United Nations' (FAO) ten elements of agroecology (Barrios et al. 2020) and Gliessman's (2016) agroecological transitions concept to provide a general framework for the analysis (Figure 1).

Given our scope, our review focus is on the scientific evidence for agroecological practices (agroecological transition level 2) and systems (agroecological transition level 3) (Gliessman 2016, Figure 1). Agroecological elements that support transition levels 2 and 3 include recycling, synergy and diversity, all of which foster ecological processes to provide ecosystem services in agricultural systems (Barrios et al. 2020).

Approaches aligned with agroecology were identified based on practices and system changes related to FAO's ten elements of agroecology (Box 1).

We propose that agroecology supports climate change adaptation and mitigation outcomes most directly by promoting resilience, diversification, efficiency, synergies, circular economy, recycling and co-learning (Andrieu and Kebede 2020). These elements do not inherently assure climate-related impacts however. For example, adaptation and resilience outcomes are not necessarily specific to climate change risk (Sinclair et al. 2019). Actual impacts depend on local conditions, for example, environment mediates the effect of crop diversification on soil carbon accrual (Hermans et al. 2020). Expected relationships between agroecology elements and climate change outcomes are summarised in Table A1 (Annex 1).

The approaches examined are not unique to agroecology and agroecology is not always labelled as such or implemented at whole system scales.

To distinguish agricultural methods in the literature aligned with agroecology, we considered field, farm and landscape-level practices that relied on enhanced ecological processes and services

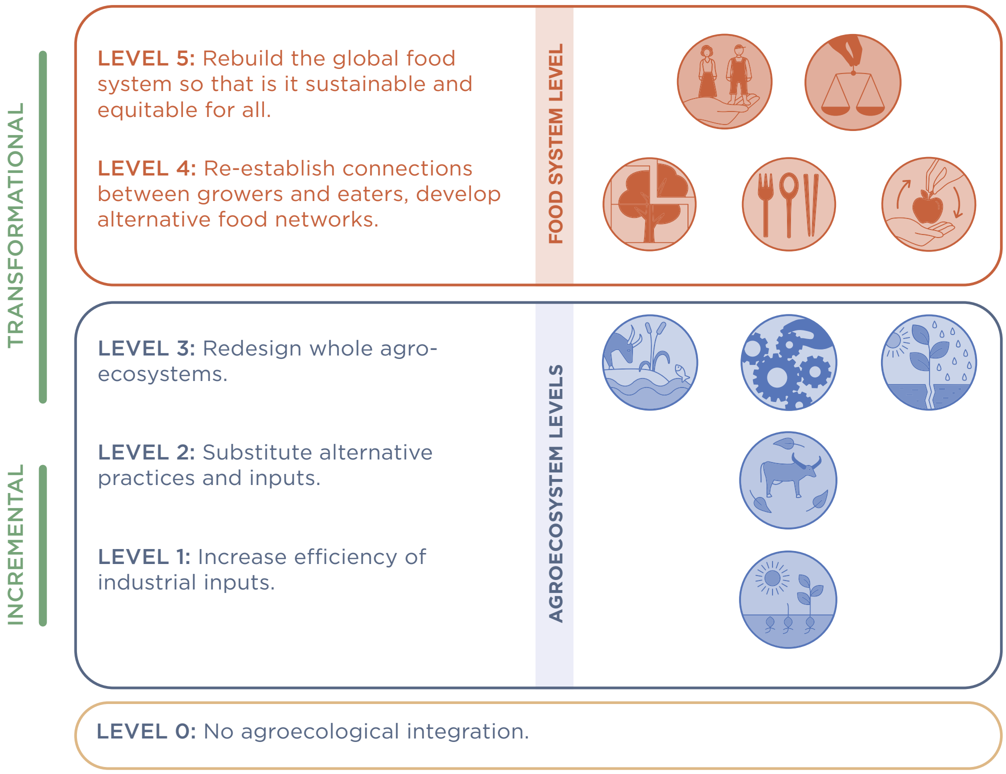

Figure 1. Agroecological transition levels as they relate to the FAO ten elements of agroecology (Source: Leippert et al. 2020).

BOX 1 – AGROECOLOGICAL APPROACHES

Sustainable intensification practices such as precision agriculture and fertiliser formulations to improve efficiency of agrochemical inputs are not considered agroecological practices here. Agronomic efficiency (Level 1 in Gliessman's framework) is insufficient on its own as an agroecological approach, especially if they are associated with other negative environmental impacts (Wezel et al. 2020). Agroecological approaches involve more than enhancing the efficiency of nutrient use and energy cycles. Instead, agroecology draws upon ecology, a scientific discipline that supports hypotheses that can be tested and used in designing agroecological practices and systems. An example is the role of diversity in resilience, an ecological theory drawn upon in AE. This stands in contrast to sustainable intensification, which is a general concept that doesn't generate design elements or hypotheses upon which to base the design of systems for agricultural development (Petersen and Snapp 2015).

compared to conventional agricultural. Examples of agroecology practices (level 2) reviewed here include diversifying crop production through growing accessory plants, e.g., cover crops, green manures and hosts for beneficial insects, managing organic nutrient sources, and biopesticides (Drinkwater and Snapp 2007). Examples of system redesign (level 3) include crop-livestock integration, landscape mosaics, agroforestry and certified organic farming (Table 1).

Research

To assess the evidence for agroecology's impacts, we addressed three research questions:

1. Climate change outcomes of agroecology: *Does agroecology support better climate change adaptation and mitigation as consequence of whole-systems approach, co-benefits in addition to productivity, or capacity to respond to extreme events?* We expect that agroecology's emphasis on whole systems lead to more comprehensive ecosystem services that support climate change adaptation and mitigation, such as agroforestry systems that support buffering of temperature and moisture regimes, nitrogen fixation and soil carbon sequestration.

2. Adaptive capacity and local engagement as a means for improving climate change outcomes: *Does agroecology provide more climate change adaptation and mitigation than conventional agriculture by emphasising locally relevant solutions, participatory processes and co-creation of knowledge?* Co-learning and development of locally relevant solutions are key elements of agroecology and are expected to better address local needs and environments, which are often complex and dynamic (Lindblom et al. 2017).

3. Agroecological transitions for large-scale impacts: *Do the programme interventions, enabling environment or barriers needed for agroecological transitions at scale differ compared to conventional systems?* Achieving agroecological transitions at significant scales to meet ambitious policy targets such as the United Nations Sustainable Development Goals (SDGs), raises questions for programme implementers about the cost of intensive community-level engagement and the feasibility of rapid, wide implementation.

2. Methods

To address the research questions above, we conducted a rapid evidence review of agroecological approaches' impacts on climate change adaptation and mitigation. An emphasis was on evidence for achieving large-scale impacts in LMICs.

We used three sources of information or the analysis: 1) synthesis and review articles, 2) articles providing primary evidence for deep dives on agroecological approaches, and 3) interviews with agricultural development organisations (Box 2).

Literature review

To identify articles for the literature review, we conducted a comprehensive search of the published scientific literature using Web of Science (WoS) for English-language articles since 1982.

The assessment of review papers allowed us to get a big picture view of the coverage of agroecology and climate change adaptation and mitigation in the literature, as well as to identify trends in key effects of agroecological approaches. Some articles included information for countries other than LMICs.

The primary evidence literature review enabled us to look in depth at the evidence in LMICs for specific approaches. Given the time available for the review, we focused on two types of approaches aligned with agroecology: nutrient management and pest and disease management. These were selected for in-depth review based on these being the major yield-suppressing factors in agriculture. Ensuring sufficient nutrient supply and regulation of pests also can be particularly challenging in low income and tropical countries, where farmers have limited access to chemical inputs. We selected articles that provided primary evidence (e.g., data from research trials, surveys) for single practices and agroecological system changes. We defined the deep dive approaches as follows:

- **Nutrient management:** Agroecological approaches based on the FAO ten elements, including practices and system levels, for nutrient management.
  - Practices included: (i) organic nutrient source (manure, compost, green manure), (ii) legumes (intercrops, rotations, push-pull, doubled legumes), (iii) crop diversity (crop/seed variety or mixed cropping, no mention of legumes), and (iv) conservation tillage, low input and mulch.
  - Systems included are listed in Table 1: (i) agroforestry, (ii) organic farming, (iii) organic integrated management including legume and conservation systems, and (iv) livestock integration representing a total of 29 papers.
- **Pest and disease management:** Agroecological approaches based on the FAO ten elements, including natural regulation and synergies, diversity, and local adaptation and farmer autonomy in pest and disease management against conventional and efficiency approaches.
  - Practices included: (i) intercropping (not push-pull), (ii) bioprotection (biopesticide/natural pesticides, botanicals), (iii) biological control (enhancement of beneficial organisms), (iv) field sanitation measures, (v) mechanical control, and (vi) improved or reduced pesticide application.
  - Systems included: (i) landscape structures (flower strips, trees integration), (ii) push-pull/ companion crops, (iii) integrated pest management, and (iv) organic farming, representing a total of 34 papers.

A total of 34 papers for pest management and 29 for nutrient management were related to approaches involving systems-level approaches to agroecology. The number of papers relating to each category of system approach for nutrient and pest management deep dives are reported in Annex I (Table A2). For nutrient management, the most frequent categories of system approach were respectively agroforestry, organic farming and livestock integration; for pest management the most frequent categories were respectively integrated pest management (IPM), push-pull/ companion crop.

We defined the indicators for climate change adaptation and mitigation by drawing from and modifying the agroecological outcomes identified in the IPES-Food report (2016). Indicators for climate change adaptation were productivity, agricultural diversity, water and nutrient regulation, soil health, pollination and pest regulation, landscape conservation, response to extreme weather and local adaptation processes (Table 1). Indicators for climate change mitigation included reduced GHG emissions and carbon sequestration in soil and biomass (Table 1).

BOX 2 – EVIDENCE USED IN THIS ASSESSMENT

To efficiently assess the evidence available for the impact of agroecology on climate change adaptation and mitigation, we compiled information from two sources: 1) selected, high quality peer-reviewed review papers relevant to agroecology and climate change adaptation and mitigation impacts or to the scaling of agroecology, based on a review of the published scientific literature; and 2) published primary evidence in scientific papers for deep dives on approaches aligned with agroecology for (a) nutrient management and (b) integrated pest and disease management, based on a systematic literature review. To assess climate change adaptation and mitigation impacts, we triangulated findings across these sources.

For the primary evidence papers, studies were only selected for analysis if they also indicated some aspect of scaling up agroecology. Scaling was defined broadly and included adoption, farmer innovation, scaling mechanisms or enabling conditions, learning, market or policy incentives and participatory research methods. (Line 32 Table A1). For these papers, we documented the presence of evidence for adaptation and mitigation impacts, but did not ascertain the direction (positive, negative, neutral or variable) or magnitude due to the need for a rapid analysis. Many of these papers were also case studies that did not provide comparison against a clear baseline.

We also conducted semi-structured interviews with twelve organisations involved in agricultural development in LMICs, including the major known organisations implementing agroecology at large scales. The aim of these interviews was to explore the conditions and constraints for scaling up agroecology, as experience with agroecology is still recent and this information was not widely available in the scientific literature.

Table 1. Indicators of climate change adaptation and mitigation and their relationship to agroecology

	Relationship to agroecology
Climate Change Adaptation Indicators	
Production	Half of the 10 elements of agroecology are directly related to production aspects (diversity, efficiency, recycling, resilience, and synergies); In AE, beyond the increase of yield, stability of yield, input autonomy, diet diversity and nutritional quality are important components for increasing CC adaptation and enhancing resilience of agroecosystems and people.
Local adaptation	Localised adaptation through farmer participation, indigenous knowledge and co-development of technical options suited to local conditions support more successful implementation and scaling up of practices with climate change adaptation and mitigation impacts. Co-creation can enhance farmers' adaptative capacity.
Agricultural diversity	Enhances generalised adaptation and resilience; can enhance mitigation by increasing vegetation abundance or period of cover with consequences for increased organic matter input to the soil.
Water and nutrient regulation	AE aim at enhancing positive ecological interaction, synergy, integration, and complementarity among the elements of agroecosystems (plants, animals, trees, soil, water) and at reducing or eliminating dependency on external inputs, contributing to nutrient leaching, underground water pollution. This can contribute to reduce vulnerability to variable climate conditions and enhance resilience.
Pollination and pest regulation services	AE aim at enhancing diversity of species, functional diversity and genetic resources and maintain biodiversity in the agroecosystem over time and space at field, farm, and landscape scales. This enhances natural regulation of pest and diseases and can lead to reduced exposure to a wide range of predators which abundance and unpredictability of occurrence is expected to increase with variable climate conditions. AE also promote reduction or elimination of pesticide use, reducing environment and people exposure to toxicity in addition to economic benefits for the farmer.
Soil health	Many of the practices promoted under AE (legumes intercropping, cover crops, rotation, agroforestry, crop-livestock integration, etc.) can have a positive impact on soil health: nitrogen fixation, soil organic matter, soil biological diversity, soil carbon stocks. An improvement of soil health has in return a range of benefits for Climate Change adaptation and mitigation: reducing Nitrogen and Carbon in the atmosphere, increasing fertility therefore production; increasing soil structure and water holding capacity which can lead to reduced soil losses due to wind or water erosion or floods.
Landscapes and conservation	AE promotes landscape-level approaches to integrate diverse challenges which cannot be tackled at plot and farm level, this also allows for sectorial integration and policy harmonisation between conflicting land uses.
Climate change mitigation indicators	
Carbon sequestration in biomass	AE practices such as permanent soil cover, agroforestry, residues retention etc. can impact C sequestration in biomass thus reducing C release in atmosphere.
Carbon sequestration in soil	Soils are carbon sinks, many of the practices promoted under AE can help increase the soil C sequestration thanks to increased soil microbial diversity and abundance, the maintenance of continuous living plant cover on soils year-round, by increasing the mass and quality of plant and animal inputs to soils. This in turn can enhance various soil processes that protect carbon from microbial turnover and contribute to climate stability.
GHG emissions	AE promotes reduced use of inorganic fertilisers and pesticides, this reduces GHG emissions related to the production of those external inputs. In addition, AE supports short value chains and local consumptions which reduces energy use for transport, processing, storage agricultural products.
Response to extreme event	Agricultural systems relying on ecological interactions, diversification, synergies among the elements of agroecosystems as supported by AE could potentially come back faster to stability after a climatic disturbance.

In the reviews, agroecological approaches and their direction of change were reported. For the review of primary evidence (literature deep dive) we examined the indicators reported on by the studies, but not the direction of change of these indicators or magnitude of their effect. Asserting directionality or magnitude would have required the control, baseline or counterfactual system for each study to be identified through close reading of the text of a study, and then the positive, negative, neutral, or variable response of agroecological approaches relative to controls to be determined. This was not feasible in the timeframe given and many papers lacked this information, so we used reporting on indicators as a proxy.

Statistically significant differences were tested using Fisher's exact test. See Annex I for a summary of the methods used to review the published literature.

Organisation interviews

We conducted semi-structured interviews of 12 organisations supporting or implementing on-the-ground agricultural development programmes. The questionnaire and names of the groups interviewed are provided in Annex I. The purpose of the interviews was to understand implementing organisations' activities relevant to agroecology and the factors enabling scaling up of these activities. Organisations were selected to represent diverse types of programme donors and implementers (5 donors, 3 non-governmental organisations, 2 farmers' organisations, and 2 government agencies) of agricultural development in LMICs. We selected organisations with a strong agroecological focus, but included several where agroecological activities were only a minor component of their programmes.

A donor advisory group and technical advisory group of agroecology, methods, and programme specialists both provided feedback on the workplan and draft report. See Annex III for the members of these groups.

Limitations of this study

- The very short time span of the study did not allow in-depth analysis such as the direction of change of climate indicators from the deep dives.
- Agroecology initiatives that are reported in grey literature were not captured in this report as it was a published literature-based evidence review.
- We did not assess future climate change impacts.
- Trade-offs between indicators of climate change adaptation and mitigation and with other ecosystems services indicators were not assessed.

3. Results

Overview of the evidence

We identified 18 review papers that provided quality evidence on approaches aligned with agroecology and their climate change adaptation and mitigation impacts. These included systematic reviews, meta-analysis and meta-analysis of meta-analysis of the literature review. In total, these papers summarised the results of 9,880 studies on adaptation, 200 studies on climate change mitigation and 225 studies on scaling conditions. The majority of the review papers were conducted at the global scale, four of them covered exclusively LMICs, five studies had 50-80% coverage of LMICs and seven covered less than 50% of LMICs. The review papers are summarised in Tables 2 to 4, organised by those relevant to climate change adaptation, climate change mitigation, and scaling and enabling conditions respectively.

The deep dive searches of the literature yielded 138 papers with primary evidence for agroecological practices and climate change outcomes and reported on some aspect of scaling practices. Eighty-five papers described practices for nutrient management review, and 53 papers described practices for pest and disease management. All studies were for sites in LMICs. The majority of papers were from authors with organisational affiliations from the United State and European Union (Figure A2 in Annex I). Collaboration of authors showed a strong trend toward North-South or North-North connections with limited South-South connections (Figure 2).

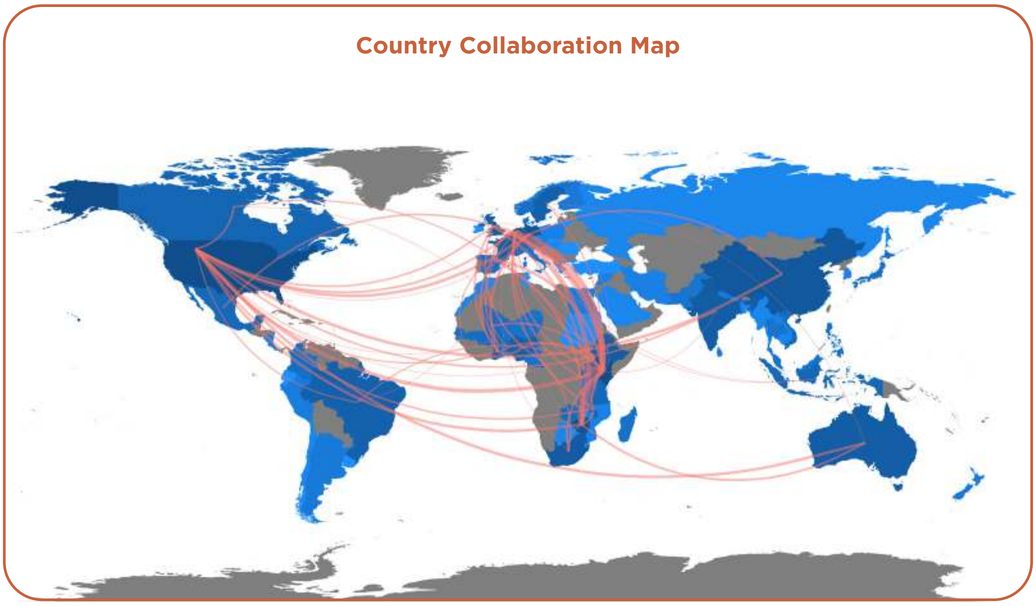

Figure 2. Number of publications by authors' affiliation country and country collaboration network with a minimum of five collaborations for the deep dive literature search outcome on nutrient management before filtering by scaling terms (818 papers).

Table 2. Synthesis papers identified for evidence on adaptation (see Annex IV for references)

Adaptation								
Ref #	**Agroecological approach**	**Adaptation Effect 1 (Production/ yield)**	**Adaptation Effect 2 (Environmental regulating services)**	**Adaptation Effect 3 (Environmental supporting services)**	**Number of studies**	**Quality and relevance of evidence**	**Region / context**	**Number and % of total of studies focused in LMICs**
1	Agricultural biodiversity and landscape diversification	Increase yield	Increased pollination, pest control with increased diversity		89 (1,475 locations) Yield based on 27 (438 locations)	M	Global	32 (36%)
2	Agricultural diversification (organic inputs, reduced tillage, crop diversification, organic farming)	Variable yield (few decreases in yield)	Increase pollination and pest control relative to simple systems	Increased environmental soil water & nutrients services relative to simple systems	98 meta-analysis; 5160 studies (41,946 comparisons)	H	Global	84 (86%)
3	Agricultural diversification (intercrop, accessory crop, agroforestry)	Increase yield with all but agroforestry (highly variable)	Biodiversity and soil benefits high with agroforestry; modest with others	Soil benefits high with agroforestry; modest with others	99 meta-analysis; 3,700 agronomic experiments	M	Global	73 (74%)
4	Organic agriculture	Yield lower and yield variability higher relative to conventional agriculture	Increase pollination, pest control, relative to conventional agriculture	Increased soil carbon, water & nutrient services relative to conventional agriculture	30 to 290 comparisons (varied with ecosystem service)	L–M	Global	12 (33%)
5	Agroecological practices	Presence of complex landscapes, inclusion of field margins and the application of cover crops => negative effects on crop yields Every other practice => positive effects on the food supply	54.2% of relationships between agroecological practices and ecosystem services had positive effect while 16.6% of the relationships were negative and 29.3% non-significant		179 scientific articles analysed	H	Global	58 (32%)
6	Agroforestry and ecosystem services sub-Saharan Africa	Positive yield	Positive impacts on water regulation	Positive impacts on soil C, fertility	126 scientific articles analysed (1,106 comparisons)	M	Sub-Saharan Africa	126 (100%)
7	Restorative actions: land sharing and land sparing	not reported	overall regulating services increase by 120% – especially pollination; biodiversity of all organism types increased by 68%	specifically considers overall supporting services increase by 42%	54 studies, 20 countries, 115 comparisons	H	Global	7 (13%)
8	Agroforestry with cacao	lower cacao yield (-25%), higher total system yield (*10)	higher biodiversity, temperature regulation	Improved soil, mixed results in soil	542 overall studies analysed; 52 studies used for detailed statistical assessment	H	Global (3 continents and 10 countries)	100%

Table 3. Synthesis papers identified for evidence on mitigation (see Annex IV for references)

			Mitigation					
Ref #	Agroecological approach	Effect on production/yield	Mitigation impact 1 (carbon (C) sequestration)	Mitigation impact 2 (other greenhouse gases)	Number of studies	Quality and relevance of evidence	Region / context	Number and % of total of studies focused in LMICs
9	Conservation tillage, organic inputs, cover crops, agroforestry	Not reported	Increased soil C	Few trade-offs with N_2O emissions	15 meta-analysis or systematic reviews	M	Global	Not specified
10	Agroforestry and conservation agriculture (CA)	Not reported	Increase soil C > 4/1000 Only for Agroforestry & CA with diversity	Not reported	66 agroforestry and 33 conservation agriculture	L	Sub-Saharan Africa	100%
11	Organic agriculture	Not reported	Enhanced soil C stocks and C sequestration relative to conventional agriculture	Not reported	74 studies (60 studies zero net input)	M	Global	9 (12%)
12	Organic agriculture	Yield lower by ~25% in organic agriculture	Not reported	Nitrous oxide lower for organic agriculture based on area; methane no difference	Meta-analysis of 12 studies	L	Temperate	1 (8.3%)
13	Ecological nutrient management	44% cases win-win: yield not reduced and nitrous oxide loss reduced	Not reported	Nitrous oxide high if N inputs high; cover crops reduce greenhouse gas emissions	129 papers (596 pairs) only 15% ecological	L	Mostly temperate	39 (30%)
14	Agroforestry systems	Not reported	High soil C in silvopastoral, biomass C in improved fallows; agroforestry C benefits high in Tropics	Not reported	86 studies	M	Global	70 (81%)

* Reference number of synthesis paper (see Annex IV.

Table 4. Synthesis papers identified for evidence on scaling and enabling conditions (see Annex IV for references)

Scaling and Enabling Conditions						
Ref #	Agroecological approach	Enabling conditions	Number of studies	Quality and relevance of evidence	Region / context	Number and % of total of studies focused in LMICs
15	Agriculture and food systems: agroecological production, processing, distribution and consumption	Crisis motivation, learning process and effective agroecological practices, social organisation, markets and policies	5 case studies	L	Central America, Mexico, Cuba, India & Brazil	5 (100%)
16	Adaptation approaches reported in literature evaluated systematically – out of >2000 only 110 presented data	Agroecology/agroforestry initiatives effective at improving income, welfare, and environment while reducing risk. Gaps identified: strengthening institutions and addressing social and racial inequity	110 papers	M	Global	68 (61.8%)
17	Scoping review of sustainable agriculture adoption	Consideration of local characteristics, conditions and priorities. Policy that explicitly considers trade-offs among economic, environment and social conditions	93 papers	L	Global	Not specified
18	Socioeconomic evaluation of agroecology	Financial capital, yield, farm productivity, human and social capital, labour demand and productivity.	17 papers	L	Global South, USA (1) and China (2)	15 (88.2%)

In addition, 72% of papers had a narrow geographic scope (i.e., single agroecosystem or country). The majority of papers concentrated in Africa (74%) and on small farms (< 2 ha or smallholder farming) (72%) (Table A6, Annex II). Climate change adaptation indicators were reported more frequently for nutrient management than climate change mitigation. There was only one paper that reported on mitigation for pest and disease management. The climate change adaptation indicator related to productivity was the most frequently identified indicator for nutrient management, whereas pollination services and pest and disease regulation services were the most frequent indicators for pest and disease management (Table A6, Annex II).

The interviews of 12 donors and implementing organisations provided evidence about their experience with scaling up agroecology programmes. Determining whether a programme promoted agroecology was not straightforward. Respondents' answers reflected differing organisational perspectives and definitions of agroecological approaches. Respondents agreed that these divergent definitions and positions on agroecology hampered action. They suggested alternative methods, such as outcome-based criteria rather than practices to define agroecological approaches. It was also suggested that agroecological programme interventions are most relevant when they support processes of farmer innovation and farmers' priorities rather than practices selected a priori. Another suggestion was to avoid the term agroecology and just focus on providing relevant technical advice that farmers need.

Organisations differed in the extent to which they emphasised distinctive aspects of agroecology (Figure A3, Annex VI). Assessing the FAO ten elements of agroecology across all organisations interviewed (Figure 3), we found that:

- Diversity, co-creation of knowledge, resilience and human and social values (i.e., livelihoods, equity) were the elements with the highest average rate across the interviewed organisations.
- Responsible governance, culture and food tradition and efficiency were the following group of elements with similar average rate across the interviewed organisations.
- Synergies, circular and solidarity economy and recycling were the elements with the lowest average rate across the interviewed organisations.

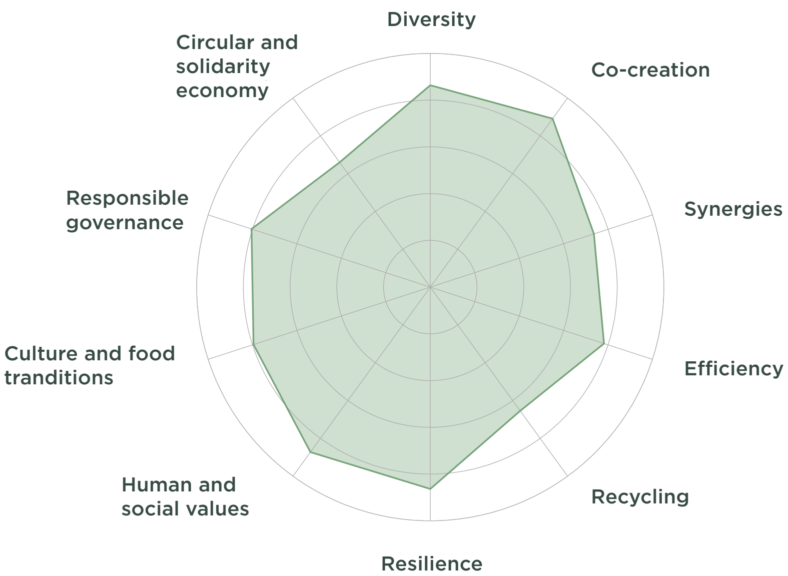

Figure 3. Level of prominence of the FAO ten elements of agroecology in policy or programmes on a scale of 1 to 5 (5 being the highest) reported as a mean of 11 out of the 12 interviewed organisations answers.

Evidence related to the research questions

1. CLIMATE CHANGE OUTCOMES

> **A. System advantage:** Does agroecology involving system interventions or system redesign provide better climate change adaptation and mitigation outcomes than single practices?

We found significant evidence that agroecological approaches that involved whole system change supported climate change adaptation (strong evidence and high agreement). One systematic review with 110 studies found that approaches aligned with agroecology provided the highest value among all approaches reviewed for effective adaptation (Owen 2020). Among agroecological elements, biological diversification on farms consistently had strong positive climate change adaptation and mitigation impacts (strong evidence, high agreement). The review papers in Table 3 showed consistent evidence for the positive impacts of diversification on pollination, pest control, nutrient cycling, water regulation and soil fertility (strong evidence, high agreement) (Beillouin et al. 2019, Dainese et al. 2019, Tamburini et al. 2020). These papers summarised several decades of research across a wide range of agroecosystems and climates. Significant evidence also existed for the impacts of agroecology on regulating and supporting environmental services. A global meta-analysis of 54 studies of ecological restoration at landscape scales showed increases in regulating environmental services of 120%, supporting environmental services of 42%, and the biodiversity of all organism types by 68% (Barral et al. 2015), which is directly related to resilience and adaptation.

The review papers also provided in-depth evidence for the impacts of agroforestry and organic agriculture on adaptation. For example, agroforestry had a positive impact on biodiversity, water regulation, soil carbon, nitrogen and fertility and for buffering temperature extremes (Beillouin et al. 2019, Niether et al. 2020, Kuyah et al. 2019). Organic agriculture improved regulating (pest, water, nutrient) and supporting services (soils, biodiversity).

The evidence from the deep dive analysis showed that system-level agroecology approaches were more frequently associated with climate change adaptation outcomes related to local adaptation ($P= 0.08$), pollination, pest and disease regulation services ($P= 0.02$), compared to single agroecological practices. However, there was no difference between practice and systems for the other climate change outcomes (See Fisher's test outputs, Annex V).

The evidence for whole-system impacts on climate change mitigation on the other hand was more limited (Table 4). There was a high-quality body of evidence that showed agroforestry was consistently associated with gains in soil carbon sequestration (Corbeels et al. 2019, Feliciano et al. 2018). Also, there is a moderate and growing body of evidence for organic agriculture and associated gains in soil carbon (Gattinger et al. 2012). There was also evidence primarily from the Global North regarding the impacts of organic farming and ecological management of nutrients on the mitigation of nitrous oxide (medium evidence, medium agreement). The mitigation of nitrous oxide (N_2O) emissions was based on greater reliance on legume sources of nitrogen and modest rates of nitrogen inputs associated with agroecology (which often relies upon recycling, synergies and diversity), compared to conventional sustainable intensification (Guenet et al. 2021, Han et al. 2017). As the greenhouse gas (GHG) footprint of outcomes depends on where system boundaries are drawn, more multi-scalar analyses are needed to capture flows of inputs and impacts beyond the farm scale.

Several research gaps were evident in the review papers and the deep dives. Overall, GHG emissions data was a major research gap. We found very few reports on N_2O, NH_3 and methane emissions associated with agricultural activities in low-income countries (Skinner et al. 2014). No reviews were found for agroecological approaches related to livestock production or crop-livestock integration. There were also few studies of landscape-scale approaches.

Most interview respondents agreed that system approaches provide substantial benefits for climate change outcomes, often more than single practices. One respondent explained that "farmers are inherently system-based and adjusting to their reality has made the work effective and created more opportunities".

B. Climate co-benefits: Do agroecological approaches provide better co-benefits to agricultural production for climate change adaptation and mitigation?

Evidence for trade-offs between yields and other climate change adaptation and mitigation services exists but is not systematically reported. There were win-win outcomes for yields and climate change mitigation associated with agroforestry, crop diversity and organic nutrient management. Diversification was associated with increased or maintained yields (although variable) compared to conventional agriculture (high evidence, high agreement). Variable and sometimes modestly lower yields were reported for organic agriculture (Skinner et al. 2014). Agroforestry systems had variable impacts on yield depending on the main crop, agro-ecological zone and soil types, including lower yields for cocoa systems. At the same time, in several reviews, agroforestry system yields in the tropics were high and no trade-offs were found with climate change services (Kuyah et al. 2019, Niether et al. 2020).

The evidence from the deep dive analysis showed that yield co-benefits were reported for a wide range of climate change adaptation and mitigation indicators (Figure 4). In addition to productivity, system agroecology approaches were frequently associated with climate change adaptation outcomes related to local adaptation (P= 0.04), pollination, and pest and diseases regulation services (P= 0.002). As we did not examine the direction of impact of agroecological approaches on pollination and pest regulation, further study is needed to assess whether impacts were positive or negative.

C. Extreme climate events: Does agroecology enable better adaptation to extreme weather events?

No systematic review and very few papers in the deep dives (less than 10 papers) were found about AE response to extreme weather conditions. We acknowledge that there are considerable challenges associated with studying response to erratic, and rare, events. This may require modelling and global analytical approaches that were outside the scope of the studies reviewed. Overall, no systemic reviews or papers in the deep dives reported on the topic of AE to enhance resilience, other than stability of yield which was an indicator reported in some studies.

2. ADAPTIVE CAPACITY AND LOCAL ENGAGEMENT AS A MEANS FOR IMPROVING CLIMATE CHANGE OUTCOMES:

Does agroecology provide more climate change adaptation and mitigation than conventional agriculture by emphasising locally relevant solutions, participatory processes and co-creation of knowledge?

We evaluated the extent of adaptation in the deep dive literature review of AE for nutrient and pest management. More than half of the papers reported adaptive capacity and local engagement processes supporting farmers to adapt practices to local conditions (80 of 138 papers). Localising processes included use of local knowledge, education or extension, technology selection by context, and farmer organisations (Figure 5). There was modest evidence that system agroecology was more frequently associated with localised and engaged adaptation, more so than practices, as shown for education and extension (P=0.085).

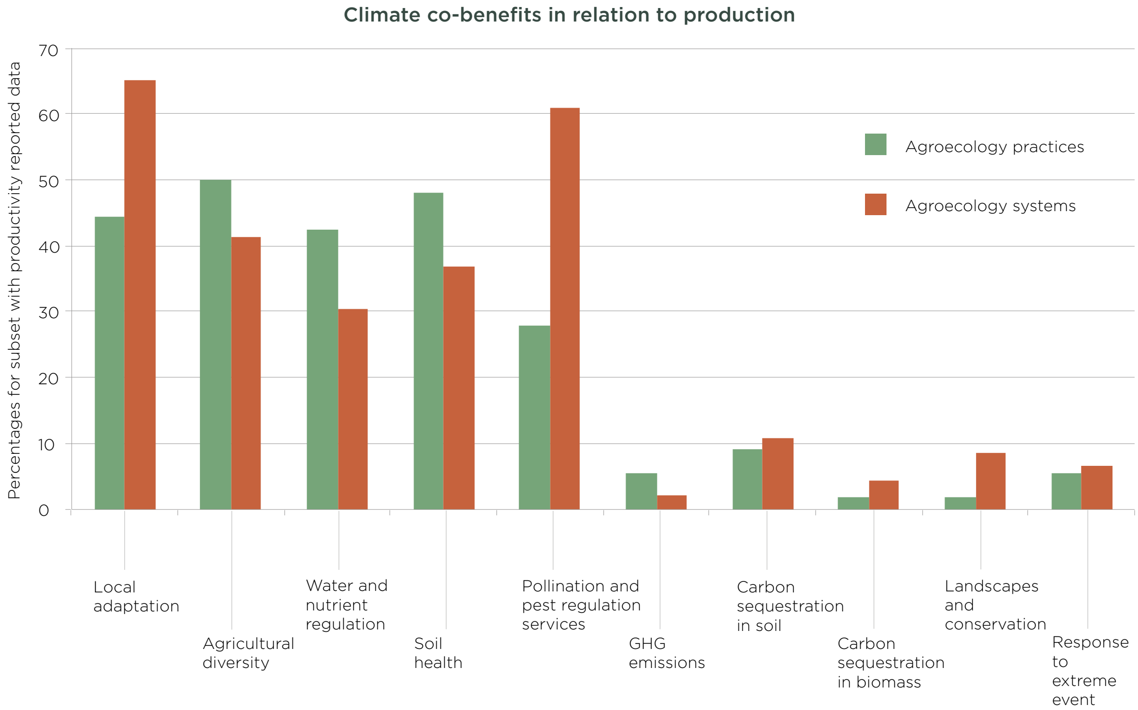

Figure 4. Percentage of papers reporting evidence for co-benefits in addition to production (100 papers), for climate change adaptation and mitigation of agroecological nutrient and pest management for practices and systems.

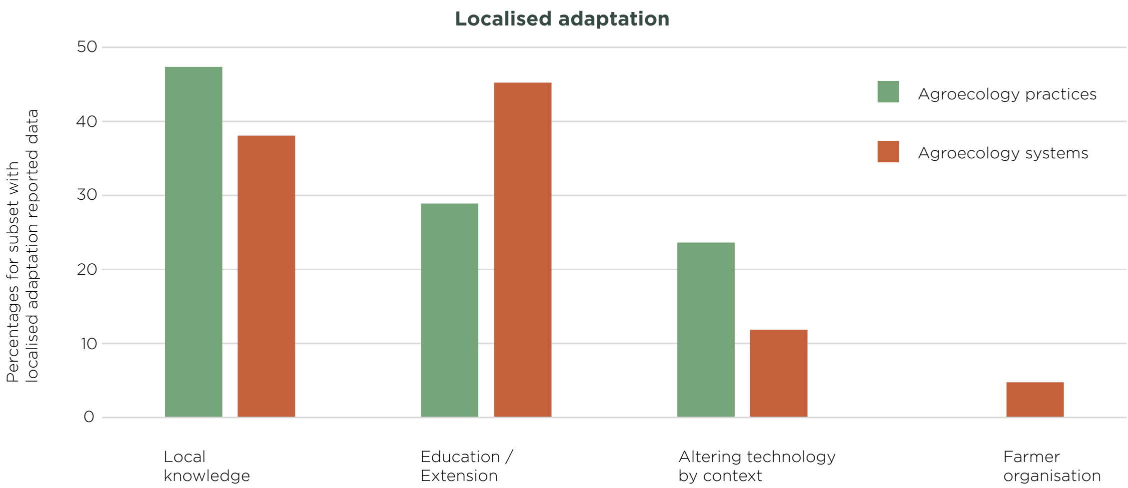

Figure 5. Papers reporting on AE nutrient and pest management were assessed for investment in adaptive capacity through local knowledge, education, and fit of technology by context for practices (38 papers) and system design (42 papers).

The majority of interview respondents reported participatory approaches as key for scaling up agroecology, in particular the participation of farmers and local communities in the co-design of projects and development of locally adapted interventions, building on local knowledge and respecting local belief systems and values. Respondents also indicated that scaling agroecology requires a community-led bottom-up approach, collective actions, farmer-to-farmer extension system. One stated, "it is slow, but the only way to go". They identified the need for self-sustaining advisory and training mechanisms, although one organisation also mentioned a need for long-term "hand-holding" support. Most interviewees (11 of 12) identified the role of civil society organisations and partnerships as a major enabling condition for scaling agroecology. With support and ownership of programmes by governments, national policy was also mentioned as essential for scaling by a number of respondents.

3. AGROECOLOGICAL TRANSITIONS FOR LARGE-SCALE IMPACTS:
Do the programme interventions, enabling environment or barriers, needed for agroecological transitions to reach many people at scale differ compared to conventional systems?

We investigated the evidence for large-scale impacts of agroecology, by asking whether the type of programme interventions, enabling conditions or barriers needed for agroecological transitions differed compared to conventional systems.

Evidence in the scientific literature relevant to scaling and enabling conditions of agroecology was poor to modest. We identified 4 systematic reviews and 48 additional papers on nutrient management or pest and disease management related to scaling. While the reviews synthesised findings from ~220 papers (Table 4), scientific robustness was mixed, and most reviews did not address agroecology at scale explicitly or compare the scaling conditions of agroecology and conventional agriculture. This is not surprising, as the complexity of scaling of agroecology poses challenges to assess systematically, especially for meta-analysis, which requires pair-wise comparisons (Krupnik et al. 2019). Most larger scale agroecology programmes are also relatively recent.

According to the literature reviewed, the drivers and enabling conditions for scaling agroecology were similar to those for conventional agriculture (e.g., bundles of new practices, advisory services, finance, market benefits, or payments) (Hazell and Wood 2008, Feder et al. 1985, Sunding and Zilberman 2001, see also references in Table 4, and Table 5). However, important differences exist. Scaling agroecology was most distinctive in its reliance on co-creation of knowledge with farmers to develop site-specific technical options, farmer organising and reliance on inclusive social movements. Market drivers differentiated agroecological production through public policy support for smallholder production (e.g., purchasing arrangements), local or regional food market development or certification, for example of organic or fair-trade goods. Government policy supported reformulation or shifts away from agro-industrial models (Mier y Terán et al. 2018). Social movements often emerged in response to agrarian conflict (Mier y Terán et al. 2018). In addition, enforced regulatory frameworks, payments for environmental services, and credit or payments conditional on environmental outcomes were important incentives associated with environmental outcomes for sustainable agriculture, in addition to market or technical interventions. In contrast, market or technical interventions were the most important incentives for adopting sustainable agriculture practices that enhanced productivity (Piñeiro et al. 2020). The reviews highlighted the need to marshal more institutional support for monitoring co-benefits to productivity, especially environmental outcomes.

Among the papers on nutrient management and pest and disease management, scaling up agroecological interventions showed similar interventions, enabling conditions or barriers compared to those for conventional agriculture. The two most common scaling interventions or enabling conditions mentioned were (1) farmer training, education and extension (23% of papers) and (2) market-based approaches (21% of papers). Common barriers included weak or absent supporting institutions or organisations (35% of papers), farmer capacity (27%), and labour (27%). The one exception was that policy change was more likely to be associated with whole-farm system intervention like agroforestry or integrated pest management than practice-based approaches (P=.097). Evidence for scaling up outcomes related to climate change mitigation or adaptation were generally lacking, as were most environmental services of agroecology.

Interviews with donors and programme implementers aligned with the findings from the literature findings and provided further insights (Table 5). Half of the organisations interviewed (6) indicated that scaling agroecology differed from scaling conventional approaches in the following ways (see detailed answers in Table A9, Annex VI):

- Agroecology is intrinsically complex and knowledge-intensive, requiring a multidisciplinary approach and making it more difficult to scale than single practices;
- The government will need to play a stronger role to go beyond short-term market-driven decisions;
- Farmers and local communities are the centre of knowledge co-design and dissemination

Common features of scaling conventional and agroecological transitions were the necessity of involving government, the lack of cooperation between government offices of agriculture and environment, and poor implementation of policies (low evidence, medium agreement).

The most frequently mentioned enabling conditions for scaling were (Figure A4, Annex VI) were:

- The role of civil society organisations and partnerships;
- Communication and digital technologies, especially videos;
- Technical advisories, including farmer-to-farmer knowledge sharing and co-learning;
- National policy.

Other important strategies were:

- Participatory research and development of practices;
- Long-term advising and training of farmers;
- Community-based finance models and ensuring farmers' direct access to funds;
- Development of markets for products, including consumer demand, local markets, shorter supply chains between farmers and consumers, and adding value through local processing;
- Government partnerships;
- Bring together people around common values – need higher level values and behaviour change;
- System (e.g., farm or landscape) interventions.

The most frequently mentioned barrier was a lack of finance and credit (5 organisations). Other barriers to scaling included:

- Initial costs and benefits are often only realised in the longer term;
- Government and educational institutions often reflected entrenched views developed over decades;
- Current government subsidy and procurement policies;
- Food security and environment programmes developed by siloed government offices and are not linked or integrated;
- Difficulty developing disaggregated solutions at scale, particularly with development programmes that do not have the capacity to directly implement activities.

Frustration concerning agroecology was expressed by some donors who experienced the agroecology movement as more political and value-based than content and evidence-driven, and not necessarily always responsive to farmers' wants (e.g., farmers wanting agro-chemicals), or no acknowledgment of existing development work related to food system transformation, diversification and agroforestry. The use of the term has become divisive and now lacks unifying power. Climate change adaptation may require some farmers to migrate or find new livelihoods and requires a broader frame of thinking than agroecology. It was noted that some conventional practices have been scaled up through conventional means yet resulted in elegant agroecological systems. More attention to the content of practices would enable more collaboration. A doubt was raised about how to make agroecology financially sustainable when markets drive decisions in the short term. These factors may act as barriers.

Agrodiversity is a key agroecology element, and recent high-level meta-analyses have found few yield trade-offs with multiple gains in ecosystem services, data that could feed into an economic analysis (Dainese et al. 2019, Tamburini et al. 2020).

While scaling up approaches aligned with agroecology differed from conventional approaches in a few key dimensions (low evidence, strong agreement), the general categories of drivers were similar. Agroecology emphasised farmer co-creation and exchange of knowledge; community-based, participatory engagement, localised solutions and social organising. Government and market interventions promoted these local processes and solutions. None of the differences by themselves were unique to agroecology but rather reflected an emphasis, often reinforced by a vision for agricultural development distinctive from market-driven, agro-industrial agriculture.

Table 5. Examples of current programmes scaling up agroecology interviewed

Name and description of programme	Location and scale	Distinctive features and highlights of approach to agroecology and climate change	What made it possible to reach scale?	Webpage link
IIRR Climate-smart agriculture/climate-resilient agriculture (CSA/CRA) Use of participatory approach to developing stable and sustainable food systems based on agroecology principles (mainly diversification, resilience and co-creation)	Philippines, Cambodia, and Myanmar	Pro-poor, participatory technology services by NGO Regenerative agriculture and agrobiodiversity conservation characterise the agroecology work Research for development approach, focused on education and building resilience Climate-smart villages	School garden program, started at pilot scales and expanded Government support Financing at the front lines	https://www.idrc.ca/en/project/climate-smart-villages-platform-resilience-womens-empowerment-equity-and-sustainable-food
McKnight Foundation – Collaborative Crop Research Program Communities of Practice (CoP) approach – ~80 projects focusing on agroecology receiving over USD 9 million in funding per year. Emphasis on farmer centred research, biodiversity, soil health, seed management, ecological pest and disease management, and ecologically intensive practices	Burkina Faso, Mali, Niger, Uganda, Kenya, Tanzania, Malawi, Bolivia, Ecuador, and Peru – involving more than 100,000 farmers overall and 17,000 in Niger	Collaborative crop research communities of practice Funding directly to the community level Emphasis on systems approach, including tree, crop, livestock systems Worked with community and religious leaders to overcome cultural resistance and make liquid waste a popular fertiliser Farmers have decision-making power, i.e., are involved in research from the design through the whole process and are the owner of the knowledge. Farmer researcher network	Working with other global organisations – cross cutting grants Policy commitment Farmer empowerment	https://www.ccrp.org/
Zero-based budget farming (Andhra Pradesh Community-managed Natural Farming – APCNF) A system wide transformation to eschew chemical inputs use principles of working with, instead of against, nature "APCNF is a farmer centric programme, follows farmer to farmer extension system and is driven by their innovations and supported by evidence from scientific research, as and when these become available" – Vijay Kumar	Andhra Pradesh, India, involving ~700,000 farmers	Farmer organising and driving a social movement Goal of maintaining plant cover through entire year (restoring water cycles for climate change mitigation) Use of bio stimulants for maintaining healthy soil microbiome Majority of funds spent on capacity building of farmers Whole village approach Long-term handholding support to each farmer, building strong evidence in favour of agroecology, support from the department of agriculture and government investments	Farmer organising, social movement, women's groups, direct finance to communities Identifying best practicing farmers and supporting them to act as Community Resource Persons (CRPs) to aid farmer to farmer knowledge sharing	http://apzbnf.in/
COMDEKS, UNDP-GEF Community-based landscape management	More than 215 projects in 20 countries spread over two phases: Brazil, Cambodia, Ethiopia, Fiji, Ghana, India, Malawi, Nepal, Slovakia, and Turkey (phase 1), and Bhutan, Cameroon, Costa Rica, Ecuador, El Salvador, Indonesia, Kyrgyzstan, Mongolia, Namibia, and Niger	Small-scale finance Participatory land use planning Suggests elements and then projects (communities-driven) identify interests. Each community decides differently based on their context. The idea is that people think in terms of ecosystem and understand what's out there to enhance resilience Focused on building social and ecological resilience in landscapes and economic sustainability at the same time. It is a slow process but an important one National coordinators supporting policy development	Agroecology still relatively unscaled, but the key to scaling is to find a good mechanism for disseminating knowledge (farmer-to-farmer knowledge sharing). Local government policy	https://comdeksproject.com

4. Discussion

Climate change outcomes of agroecology

Agroecological approaches associated with diversification supported climate change adaptation (strong evidence and high agreement), and to a lesser extent, climate change mitigation (medium evidence, medium agreement). This included positive impacts of diversification on pollination, pest control, nutrient cycling, water regulation and soil fertility. Soil carbon regulation was the most frequently observed form of mitigation, and there is evidence (medium evidence, high agreement) that diversification with perennials promotes soil carbon sequestration. Diversification is a principle of AE and a key element implemented at multiple scales, including field, farm and landscapes. We note that we did not assess AE relative to other pathways, and there may well be multiple pathways to promoting diversification. At the same time, there are global trends towards cropping pattern simplification with many unintended negative consequences, including poor climate change outcomes. AE approaches often rely upon diversification and offer lessons in how to scale diversification. Much work remains to be done and interview respondents highlighted barriers that need to be overcome.

Agroforestry and organic agriculture are widely associated with agroecology, and both were associated with substantial gains in carbon sequestration and modest or no yield trade-offs, as shown by a number of systematic and often global reviews (Leippert et al. 2020, Smith et al. 2019, Tamburini et al. 2020). However, landscape-scale evaluation of climate change mitigation is understudied, which leaves unanswered the critiques of organic agriculture in particular (Connor 2018).

There was also evidence – primarily from the Global North - regarding greenhouse gas emissions as organic farming and ecological management of nutrients were associated with mitigation of nitrous oxide (medium evidence, medium agreement). A comparison of agroecological practices and system approaches showed that both supported climate change outcomes. However, there was a system advantage related to local adaptation, and pollination and pest regulation services. There were evidence gaps in agroecological approaches that included livestock integration and landscape-scale redesign, as noted by others (Skinner et al. 2014). There was limited data on GHG emissions for the tropics and almost no evidence regarding resilience to extreme weather events. One study that monitored farm plots in Nicaragua under conventional and participatory, sustainable management found that the later was associated with resilience after Hurricane Mitch (Holt-Gimenez 2002). We also point to the large body of literature in ecology on biodiversity in natural systems as key to providing 'insurance' services (Mace et al. 2012). Further, a country-wide, multi-year study has shown yield stability to be highly associated with biodiversity on smallholder farms in Malawi (Snapp et al. 2010), and other studies in our deep dive literature review did assess yield variability, which provides a starting place for improved understanding of resilience and AE taken together, the evidence is consistent with AE approaches as enhancing the resilience of farming systems (Schipanski et al. 2016).

Agroecology promotes adaptation through local engagement and co-knowledge generation

An overall finding was that agroecological approaches prioritise adaptive capacity, which improves climate change outcomes (medium evidence, high agreement). This was supported by evidence from both the deep dive literature review and interviews. Only one synthesis of synthesis review reported on adaptation; it highlighted the role of agroecological approaches in supporting effective adaptation (Owen 2020). Interviews with representatives of organisations involved in scaling agroecology often stressed the role of co-knowledge and localised adaptation. This was consistent with the deep dive findings for nutrient and pest and disease management, where the majority of primary evidence reviewed reported agroecological approaches involving co-creation and sharing of knowledge, important in delivering climate change impact.

Taken together, our findings are consistent with agroecology as an approach that prioritises processes that enhance adaptive capacity and fit local conditions, through indigenous knowledge, education, technology re-design, participatory learning and local capacity building. This is an important differentiating aspect of agroecological approaches operating at both practice and system levels. This is in addition to agroecology's ecological elements, which are environmentally sound principles, e.g., diversity, synergy, efficiency, and recycling. Adaptive capacity can be challenging to document and has been overlooked in some agroecology reviews, but we found evidence that it is important. Further, we suggest that an outcome-oriented definition of agroecology, which includes adaptive capacity and co-generation of knowledge, could be a useful way forward in scaling agroecological approaches to reach more people and achieve development goals. This can help in overcoming the divide on agroecology which is less on the scientific concept of AE but rather on the type of value chains (short/long), the level of intensity in agricultural use (low/high input agriculture), market orientation (export oriented/local consumption) etc.

Agroecological transitions rely on local processes

Agroecology was not evaluated relative to conventional intensification, due to the scope of a rapid evidence review. Agricultural development following conventional intensification that has in many cases relied on technology transfer approach is not supportive of local adaptation, and AE may offer an alternative. More research is needed on how to promote scaling, but AE elements include co-creation with stakeholders and investment in local adaptation capacity, which support climate change adaptation (Leippert et al. 2020, Owen 2020). We acknowledge that scaling of participatory approaches poses challenges, including human and financial resources to support engagement in co-knowledge generation with millions of farmers and other stakeholders. There are innovations in local learning that should be evaluated and successful ones promoted, such as information and communication technology informed campaigns and digital approaches to promote action learning approaches. An example is provided by scaling of farmer field school approaches that have enabled large-scale reduction in pesticide use and enhanced biodiversity in rice systems (Heong et al. 2014).

Scaling also relied on market and policy measures that privileged local production. Together with the inherent complexity and knowledge intensity of agroecology, these factors sometimes incurred more cost and time but then enabled greater impact and benefits in the long term. More evidence on scaling is needed, especially for mitigation outcomes in Asia and Latin America.

These findings are broadly consistent with the wider literature. Reviews for scaling of sustainable agriculture (Piñeiro et al. 2020), agroforestry (Mercer 2004) and soil carbon sequestration (Ng'ang'a et al. 2019) provide evidence for multiple drivers of adopting new practices but do not quantify trade-offs and climate change mitigation or adaptation outcomes. The 2019 report of the High Level Panel of Experts on Food Security and Nutrition (HLPE 2019), notes gaps in information about agroecology outcomes compared to conventional approaches, including resilience to climate change. The HLPE identified the need for more information to support agroecological transitions, particularly to overcome lock-ins to undesirable development pathways. Barriers to a transition to agroecology include governance (e.g., trade, power imbalances), economic factors (e.g., lock-in path dependencies, corporate consolidation), resource factors (e.g., low soil fertility, lack of labour), social and cultural factors (dietary changes, consumer expectations) and knowledge factors (e.g., metrics that address externalities, market options). They also indicate the need for better evidence about how to scale agroecological approaches to support democratic processes and equity, a critical point for climate change mitigation, as wealthier farmers tend to produce more environmental outcomes (Piñeiro et al. 2020).

In spite of these findings, a major question is to what extent scaling up agroecology may restrict farmers' options and become a poverty trap by maintaining the status quo and not providing access to the growth possible through industrial and corporate models (Mugwanya 2019). There is a lack of data or scenarios showing the impacts of agroecological transitions on economic development, and it is a complex topic that was deemed beyond the scope of this review. This topic is a key research priority addressed by the Transformative Partnership Platform (TPP) on agroecological approaches, aiming to document and evaluate the socioeconomic viability of agroecological practices across Africa. This is supported by French funding and coordinated by the agroecology research priority of the CGIAR Programme on Forests, Trees and Agroforestry (FTA).

Agroecological principles encourage farmers and local communities to act as decision-makers and leaders in finding solutions for their own issues. In relation to this, the idea of scaling has a very specific meaning in agroecology. In fact, agroecological science and practices are intrinsically linked to farmers' knowledge in relation to the specific geographic contexts they live in and constraints they encounter. Therefore, the innovation developed by farmers is inherently locally adapted. General principles and knowledge can emerge from one geographic context and inform another with similar agroecological and pedo-climatic conditions, even though the scaling of the principles and knowledge will have to build on organisational and institutional context (Mier y Terán et al. 2018). Therefore, scaling agroecology requires attention to mechanisms that support scaling of adaptation, learning, participatory decision-making, and social organising.

Defining agroecology and working across organisational perspectives

Tackling climate change will require broad cooperation and diverse approaches. Operationalising agroecology across organisations with different political visions for development will require transcending the many labels for sustainable agriculture and climate change (e.g., climate smart agriculture, regenerative agriculture), including agroecology. This means focusing more on the content of the changes needed or using an outcome-based approach to defining agroecology. Attention to outcomes relevant to the SDGs such as climate change resilience, environmental health, gender equity and social inclusion, soil health, biodiversity conservation, healthy diets and resource efficiency could provide common points of reference (Leippert et al. 2020). Another outcome-based approach is to aim to develop a negative ecological footprint of current practices (HLPE 2019).

Toward agroecology transitions for climate change impacts

STATE OF INVESTMENT IN AGROECOLOGY

Recent reviews of funding for agroecology found that most donors at least partly support agroecological principles (Biovision and IPES Food 2020, CIDSE 2020), which was confirmed in interviews with programme experts for this study. However, the majority of agricultural investment (63%) is reinforcing or making minor adjustments to existing systems (Biovision and IPES Food 2020) despite calls for food system transformation (Steiner et al. 2020). Funding for agroecology is a small proportion of major global agricultural development investment. About 80% of the EU's funding to FAO, International Fund for Agricultural Development (IFAD) and the World Food Programme (Figure 6a) and 80% of the Green Climate Fund's funding (Figure 6b) flow to activities supporting conventional or efficiency-oriented agriculture such as sustainable intensification (CIDSE 2020). Comparison of project funding from Switzerland, the Bill and Melinda Gates Foundation (BMGF) and Kenya's research institutes shows that 85% of the BMGF-funded projects and more than 70% of Kenyan research institute funding focuses on industrial agriculture or increasing its efficiency (Biovision and IPES Food 2020). These analyses do not examine flows related to climate change adaptation or mitigation.

Requirements of donors, such as short-term reportable returns on investment, can be a constraint to funding investments that mostly yield benefits in the long-term. At the same time, major donors have made explicit commitments to long-term agroecology goals; these include France, Switzerland, Germany, the FAO and IFAD (Biovision and IPES Food 2020).

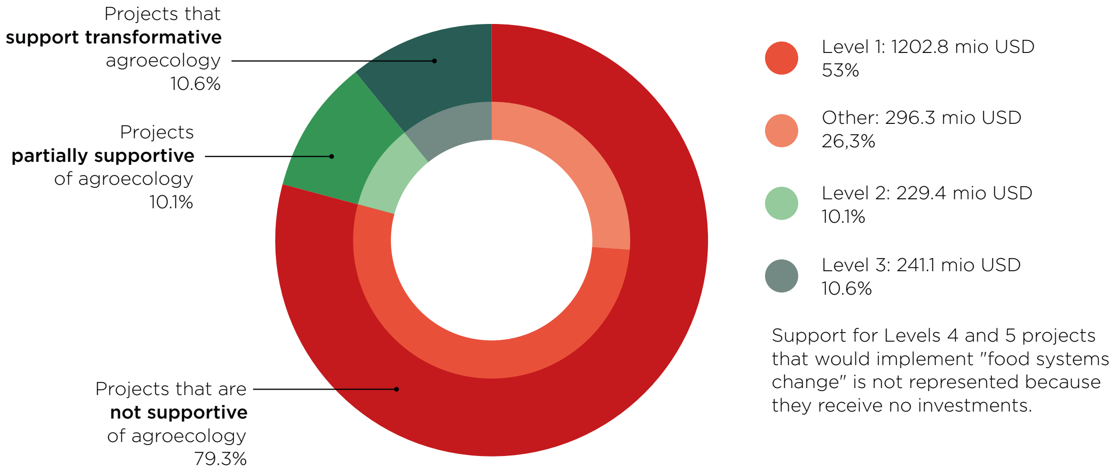

Figure 6a. Overview of the degree to which EU's funding to FAO, IFAD and World Food Programme integrated agroecology in agriculture research for development (AgR4D), provided as total investments per category in USD millions for the total amount of GCF agricultural projects between 2016-2018. Source: CIDSE 2020

Operationalising agroecology

Despite the challenges associated with scaling up agroecological approaches, this review suggests several models of implementation for achieving scale, drawing on current programmes:

- Small-scale finance (COMDEKS, UNDP-GEF);
- Collaborative crop research community of practice (McKnight Foundation);
- Farmer organising and driving a social movement (Andhra Pradesh Community-managed Natural Farming);
- Participatory, pro-poor technical support (International Institute for Rural Reconstruction).

A research priority is evaluating the impacts and drawing lessons from these programmes and others, such as those of the Scaling up Agroecology Initiative of FAO and partners in Senegal, Mexico, and regional programmes in West Africa and Latin America and the Caribbean.

This review concurs with recommendations regarding long-term funding modalities, setting targets for outcomes that include environmental services and climate change outcomes and seeking systemic change to building farmer capacities and incentives (Biovision and IPES Food 2020). Rather than treating climate change adaptation and mitigation as "co-benefits," which risks limiting progress to incremental change, there is a need to actively manage for climate change benefits. Key programme elements to support agroecology and climate change outcomes include:

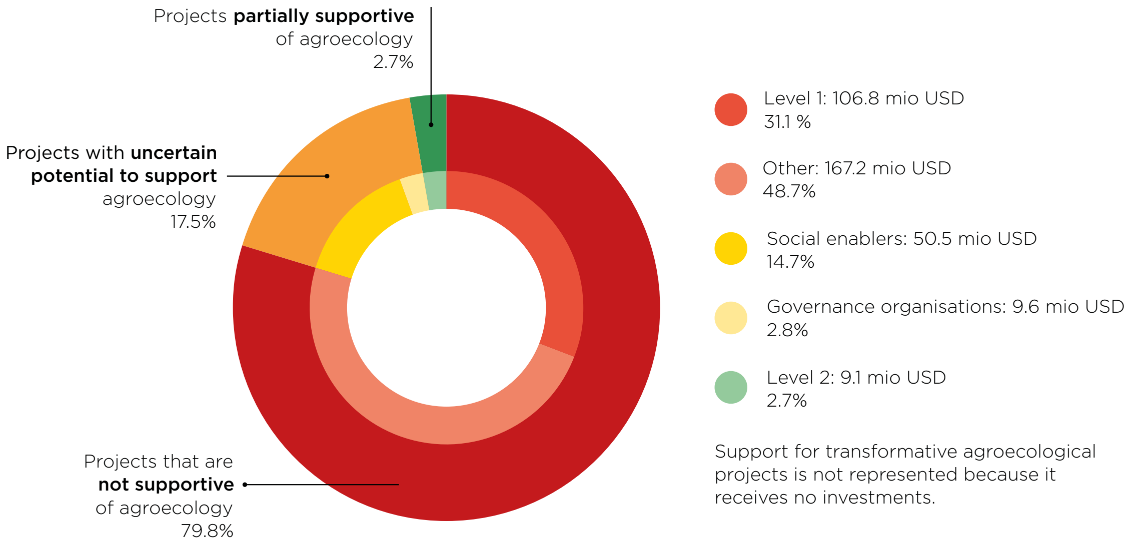

Figure 6b. Overview of the degree to which the Green Climate Fund's funding integrated agroecology in AgR4D between 2016-2018, provided as total investments per category in USD millions for the total amount of EU flows towards FAO, IFAD, WFP (2016-208). Source: CIDSE 2020

- Processes for farmer co-design of practices with research, to generate relevance, fit the local context, and enable ongoing adaptation to climate risks rather than pre-determined technical packages;
- System approaches, including agroforestry, organic, legume diversification, integrated pest and soil management, and landscape management designed for flexibility to be contextually specific and effective for climate change mitigation and adaptation;
- Strengthening extension-farmer networks, and farmer-based organisations to support finance, training, farmer-to-farmer knowledge exchange, local education, monitoring and decision making;
- Market, institutional and policy arrangements that promote these approaches and overcome the tendency of environment and climate change objectives to be treated as separate from agricultural development, and address trade-offs between environment or social outcomes and productivity or profitability to support more rapid and large-scale impacts, including nationally determined contributions (NDCs) to the Paris Agreement;
- Institutional support for monitoring environmental services, assessing performance that considers more than productivity or profitability, using indicators of climate change mitigation and adaptation; this is needed to inform policy across multiple dimensions and support annual reporting to the UN Framework Convention on Climate Change (UNFCCC). Recent efforts led by FAO to systematise monitoring AE performance show a way forward, through Tools for Agroecological Performance Evaluation (TAPE), (Barrios et al. 2020, Mottet et al. 2020). The USAID supported SI Assessment Framework also provides systematic approaches to outcome-based assessment and trade-off analysis (Grabowski et al. 2018, http://www.k-state.edu/siil/resources/framework/index.html).

Knowledge gaps

Improved climate change outcomes from agroecology and alternatives rely on evidence. This includes improved understanding of links in agricultural performance to impact on the environment and effective climate change adaptation pathways. There is currently almost no primary evidence on tropical agriculture GHGs (N2O and CH4) and approaches that can mitigate these or how to buffer effects of extreme weather events. Longer-term studies with innovative approaches such as benchmark on-farm studies, participatory modelling and community engaged research is urgently needed to understand climate change outcomes at multiple scales, while building capacity to adapt. Policy research is also needed on effective ways to scale approaches that are effective at achieving environmental services and other climate change outcomes without compromising productivity services.

5. Recommendations

This rapid evidence review identifies agroecology related practices, systems and approaches that address climate change outcomes. It also points to critical knowledge gaps.

Donors investing in agroecology should consider how to position and define their work in ways that transcend divergent definitions and political versus scientific perspectives and avoid the need to determine whether practices are agroecological or not. One approach is to focus on the content of approaches and outcome-based definitions and indicators. Assessing multiple dimensions of performance is important to achieve climate change outcomes, including productivity, but also environmental services, climate change response, and adaptation. A number of agroecology frameworks exist that can inform this work (Wezel et al. 2020, Kapgen and Roudart 2020, Grabowski et al. 2018) and can be used to evaluate performance and trade-offs associated with agricultural development approaches, such as the Tools for Agroecological Performance Evaluation (TAPE by FAO), Sustainable Intensification Assessment Framework (USAID-supported), and FAIR Sahel by the French Agricultural Research Center (CIRAD). Labels like agroecology can still be expedient for communication; the point is to spend less time debating what is or is not agroecology. We note that valuation of a range of agroecological benefits can be difficult to quantify (e.g., environmental and social benefits), and economics often reflect current policy context and short time horizons.

In prioritising agroecological approaches that support climate change adaptation and mitigation, donors can focus on approaches where there is strong evidence and high agreement. A large body of evidence points to diversity supporting the climate change outcomes both for adaptation and for mitigation. Programme implementation experts also indicated diversity as a common and scalable intervention. The evidence from the literature and programme experts' experience also strongly supports co-design and co-development of knowledge with farmers or communities to enhance adaptive capacities and locally relevant solutions. Investment in technologies or high-level market or policy interventions alone is not sufficient.

To implement these approaches at scale, donors can support shifting institutional practices and capacities. Priorities for governments, donors and policy makers include:

- Creating incentives and capacity that support diversification at multiple scales, and local adaptation;
- Better linking funding and performance indicators in agriculture to environment and climate change outcomes. Support for agroecology approaches is an important way to achieve this linkage as these approaches were shown in this review to provide a broad range of environmental services, including regulatory services, diversification and carbon sequestration.

To address knowledge gaps, research priorities include:

- Barriers and opportunities for scaling out of diversification and local adaptation processes, across landscapes and regions, through multiple agricultural development pathways that include agroecology;
- Research in tropical and low-income countries on climate change adaptation to extreme weather and quantitative assessment of greenhouse gas emissions;
- Scientific documentation of the effectiveness of agroecological approaches compared to alternatives, including performance in terms of environmental, social and cost-effectiveness, and direction of impact on climate change outcomes;
- Evaluation of the impacts and identification lessons from programmes presently implementing agroecology at scale;
- South-South research collaboration.

ANNEX I. CONCEPTUAL FRAMEWORK AND METHODS

1. Conceptual framework

The relationship of the ten elements of agroecology, according to FAO, can be related to climate change adaptation and mitigation (Table A1)

Table A1 . Potential relationship of FAO agroecological elements to climate change adaptation and mitigation

FAO elements most directly relevant to climate change	Adaptation	Mitigation
Resilience	Enhances generalised adaptative capacity	Mitigation practices rebound from disturbance
Diversity	Enhances generalised adaptation by spreading risk across different elements of the agroecosystem and livelihoods	Can increase biomass or extent or length of cover cropping resulting in aboveground and below-ground carbon sequestration Diversification can reduce N_2O under some conditions
Efficiency	Generates surplus for generalised adaptation and resilience Efficient water use supports adaptation in places facing water stress	Efficient water use can reduce energy use or paddy rice flooding periods, reducing emissions Efficient fertiliser use avoids or reduces nitrous oxide emissions Efficient herd compositions can reduce livestock emissions Efficient energy use reduces CO_2 emissions
Synergy	Ecological synergies (e.g., nitrogen fixation) can generate surplus production or ecosystem services for generalised adaptation and resilience Linkages with mitigation	Linkages with adaptation can generate more residue inputs Manure management and use of manure as a substitute for synthetic fertiliser produced with high fossil fuel energy inputs
Circular economy and recycling	Generates surplus for generalised adaptation and resilience	Use of waste can reduce emissions, such as use of manure for synthetic fertiliser or biogas as substitute for fossil fuels
Co-creation of knowledge	Can enhance farmers' adaptative capacity and relevance of options by bringing together multiple sources of knowledge and enabling technical options best suited to local conditions	Can support innovation and relevance of options by bringing together multiple sources of knowledge and enabling technical options best suited to local conditions

2. Review of synthesis papers for nutrient management and pest and disease management

The review of synthesis papers aimed to identify paper reviews of research with primary evidence, i.e., studies that were primarily experimental or observational in nature and demonstrated agroecology performance or scaling up. We identified which papers were systematic reviews and classified these as (i) meta-analysis of the literature and (ii) systematic reviews that are rigorous and transparent by stating the search terms used and the numbers of studies included in the review.

Criteria for removal included 'reviews' that considered fewer than five studies or did not state how many studies were reviewed. Geographical scope needed to include more than one country. A study was also removed if it did not include agricultural systems and only reported on natural areas, forestry or rangeland.

Expert judgement was used to identify other relevant reviews and then develop a "best set" of top reviews. The reviews chosen were included based on the quality of the study, strength of the evidence and relevance to agroecology and climate change impacts in low- and middle-income countries. The criteria included the number of studies reviewed, systematic process and transparency of the review, global or appropriately targeted to regions of interest.

Review papers were evaluated qualitatively, and key points were highlighted in three tables. These tables were based on each study's primary topic: climate change adaptation, climate change mitigation, and scaling. In the case of overlaps, such as regarding soil carbon supporting services, if soil carbon was the primary indicator considered in the study, then it was reported under climate change mitigation. However, if multiple ecosystem services were reported, including soil C, then the study was included under climate change adaptation. Evidence gaps were then assessed.

3. Nutrient Management and Pest Management Deep Dives

Literature searches for both the nutrient management and pest management deep dives were performed within the Web of Science (WoS) Core Collection using the same search criteria, except for two search rows, which included search terms specific to the respective deep dive (Tables A3 and A4. All searches were based on articles published from 1982 to the present.

Figure A1 shows the steps taken to identify and refine candidate articles for each deep dive. Initially, separate WoS searches were conducted to identify literature corresponding to agroecological practices (levels 2, i.e., "practices") and agroecological systems (level 3, i.e., "systems") as proposed by Gliessman (2016). However, the different search results did not match the defined levels, so the agroecological practices and systems search results were combined (i.e., Levels 1, 2 and 3). Each article's agroecological level was later determined when performing data entry. We searched for articles that included key terms related to agroecological practices that (i) were conducted in developing countries, (ii) were not related to agroecosystems, agro-ecological zones, meta-analyses, review, opinion, or perspective articles, (iii) included indicators of climate change mitigation, adaptation, or related co-benefits, and (iv) included terms related to scaling up (Figure A1, Tables A3 and A4).

Figure A1. Stepwise procedure taken to identify and narrow candidate journals for nutrient management (bold text) and pest management (light weight text) deep dives.

Multiple iterations of the deep dive search terms were tested, and the corresponding results were reviewed to evaluate their relevance to agroecology and climate change adaptation and mitigation. Once the final WoS search was conducted, the results were narrowed further by excluding any publications that WoS categorised as a review, proceedings article, early access, book chapter, data article, opinion-piece, or editorial material. Lastly, all remaining articles' abstracts were reviewed using the software system Rayyan (Ouzzani et al. 2016). After reviewing abstracts, 85 and 53 articles were selected for the nutrient management and pest management deep dive data collection, respectively (Figure A1). Studies were then combined into one dataset with duplicates removed, resulting in 138 studies for the deep dive analysis. All studies were for sites in LMICs. The majority of papers were from authors with organisational affiliations from the United State and European Union (Figure A2)

Each study was assessed in terms of its relationship to the five research questions.

The studies were characterised as relevant to agroecological management of nutrients, pests or both. Up to two agroecological interventions per article were characterised according to the type of agroecological approach. For nutrient management, interventions were categorised as:

Nutrient Management Categories
1= Agroforestry
2= Organic farming
3= Landscape mosaics
4= Livestock integration
5= Organic nutrient source (manure, compost, green manure)
6= Legumes (intercrops, rotations, push-pull, doubled legumes)
7= Crop diversity (variety studies or mixed cropping no mention of legumes)
8= Conservation tillage, low input and mulch
9= Regenerative agriculture
10= Other

Pest Management Categories
1= Intercropping (non-push-pull)
2= Landscape structure (flower strips, trees integration)
3= Push-pull/companion crops
4= Bioprotection (biopesticide/natural pesticides, botanical)
5= Biological control (enhancement of beneficial organisms)
6= Field sanitation measures
7= Integrated pest management
8= Organic
9= Mechanical control
10= Improved or reduced pesticide application
11= Other

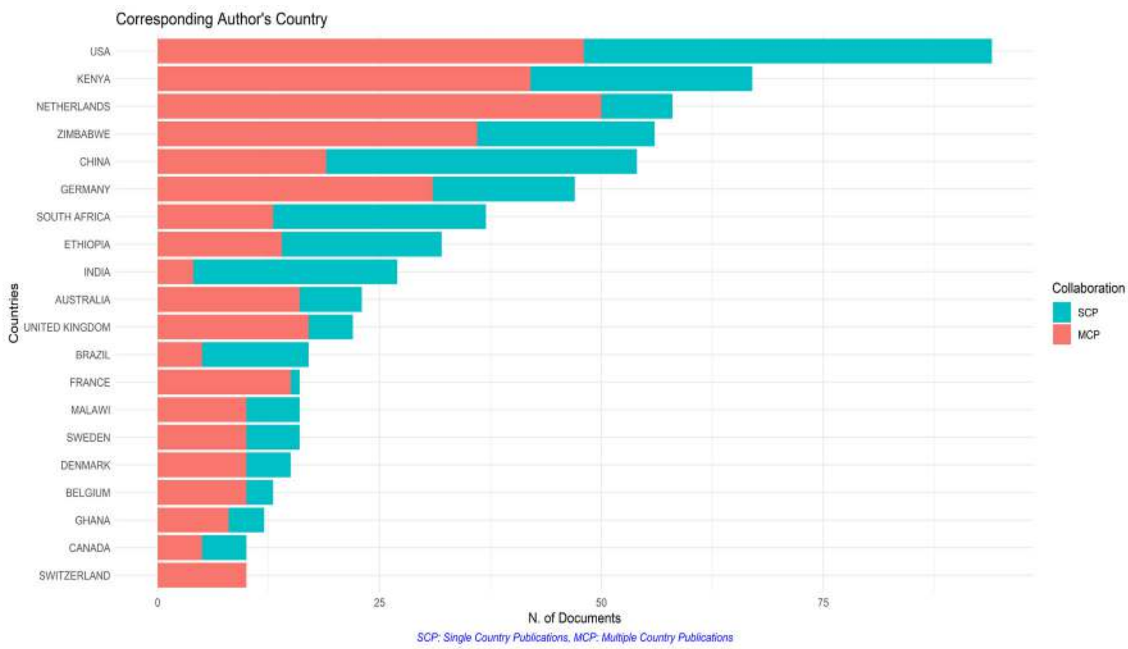

Figure A2. Number of single and multiple countries publications on the basis of for the deep dive literature research on nutrient management before filtering by scaling terms (n=818 papers).

Further characterisation of each study included the approach level (practices v. system) (Table A2), the extent of local adaptation conducted (local or indigenous knowledge, extension and education, altering technology by context, and involvement of farmer organisation), geographic scope, the relative size of farms referenced or participating in each study, and the quality of the study. A study's quality was determined by the type of evidence (empirical or modelled) and whether the study triangulated evidence (i.e., used multiple methods).

Each study's assessment of climate change mitigation, adaptation, or co-benefits in relation to the agroecological intervention(s) was recorded. More specifically, whether or not the study reported on productivity, agricultural diversity, water and nutrient regulation, soil health, pollination services and pest regulation, greenhouse gas emissions, carbon sequestration in soil, carbon sequestration in biomass, landscapes and conservation, or response to extreme events was recorded.

Finally, whether the study considered enabling conditions or barriers related to scaling-up the intervention(s) of interest was also reported. These were as follows:

- Scaling enabling conditions: training, education, or advisory services; co-learning or farmer participatory processes; other stakeholder participation and partnerships; social movement; other organisational or institutional strengthening; market access or prices; increased benefits to farmer; farmer preferences met; finance or credit; subsidies; input access; food or agriculture policy; land or tree rights, access, or tenure; ecosystem market or payment; certification or standards; consumer awareness or demand; or other.
- Scaling barriers: biophysical; farmer capacity; others' capacity; labour; farm inputs; finance or credit; market access or prices; other farm or household conditions; land or tree rights, access, or tenure; policy; weak or lacking institutions or organisations; power relations, inequity, or marginalisation; or other.

Table A2. Agroecology systems included in the systematic literature review for AE nutrient management and AE pest management are shown here

Agroecology System Counts			
Nutrient Management		Pest Management	
Agroforestry	9	Landscape structure	3
Organic farming	6	Push-pull/companion crop	8
Livestock integration	4	Biological control	1
Organic nutrient source	3	Integrated pest management (IPM)	18
Legumes	2	Organic	3
Conservation tillage	2	Other	1
Other	3	-	-
Total	**29**	**Total**	**34**

DATA ANALYSIS

To get an initial overview of the diversity and relationship of topics and the main authors associated with those topics, we used the literature search outcome before filtering by scaling to perform two network analyses, one for pest management (354 articles) and one for nutrient management (818 articles). The articles covered the period 1982 to 2020. We exported the title, abstract, key words and cited references of those articles and analysed them using Cortext Manager (www.cortext.net) text mining software. We selected the first 300 most occurring terms, merged identical terms appearing in different spellings and performed a network analysis with the first 75 most frequently occurring terms within the titles, key words and abstracts. The results are shown in Figures A3 and A4 in Annex II.

Frequency tables in Microsoft Excel were used to determine the total number of studies characterised by the various criteria described above. Fisher's exact test, employed for categorical datasets with small counts (Bower 2003), was then performed to analyse the statistical strength of observed trends using R (R Foundation for Statistical Computing, Vienna, Austria) within RStudio (R Studio Team 2015). Specifically, we tested each hypothesis for significant differences amongst agroecological levels, local adaptation, intervention(s), and scaling enabling conditions/barriers:

RESEARCH QUESTIONS

We examined the following research questions:

1. Climate change outcomes of agroecology: *Does agroecology support better climate change adaptation and mitigation due to whole-systems approach (138 papers), co-benefits in addition to productivity (100 papers), or capacity to respond to extreme events (less than 10 papers, not tested)?*

2. Adaptive capacity and local engagement as a means for improving climate change outcomes: *Does agroecology provide more climate change adaptation and mitigation than conventional agriculture by emphasising locally relevant solutions, participatory processes and co-creation of knowledge (138 papers)?*

3. Agroecological transitions for large-scale impacts: *Do the programme interventions, enabling environment or barriers needed for agroecological transitions at scale differ compared to conventional systems (48 papers)?*

Table A3. Search terms for nutrient management deep dive. Note that TS refers to topic, TI refers to title.

Row	Search Terms	Description of Search Terms
1	TS=(nutrient* OR nitrogen OR phosphorus)	Only for nutrient management deep dive
2	TS=((intercrop* OR "crop association*" OR “doubled up” OR “doubled-up” OR “legume diver*” OR “rotat* diver*” OR “mixed crop*” OR "mixed cultivar*" OR "cover crop*" OR “green manure” OR “living cover”) AND (agricultur* OR farm* OR agroeco*))	Cropping practices
3	TS= ((biofertili* OR "organic fertili*" OR manur* OR compost* OR mulch* OR "crop residue*" OR biopesticide* OR bioprotection OR "biological control" OR biocontrol*) AND (agricultur* OR farm* OR agroeco*))	Soil amendments and pest management
4	TS= ((“perennial grain*” OR “push-pull” OR “recycl* nutrient*” OR “integrated crop” OR “integrated soil” OR “couple* carbon” OR “tighten nutrient” OR “nutrient budget”) AND (agricultur* OR farm* OR agroeco*))	Pest management, nutrient recycling, and diversification
5	#1 AND (#2 OR #3 OR #4)	Combine search terms specific to the nutrient management deep dive with the search terms for Agroecological Practices
6	TS=((“crop livestock system” OR “integrated crop livestock” OR “crop-livestock” OR “agro-sylvo-pastoral” OR “sylvopastoral” OR “rotational grazing” OR diversif* OR “nutrient cycl*” OR “crop interaction” OR “pest-crop interaction” OR ecolog*) AND (agricultur* OR farm* OR agroeco*))	Crop-livestock integration
7	TS=((“farmer participatory” OR “action research”) AND (agricultur* OR farm* OR agroeco*))	Participatory action research
8	TS=((("*ecologic* intensification" OR “low input” OR permaculture OR holistic OR “integrated organic” OR “certified organic” OR agroforest*) AND (agricultur* OR farm* OR agroeco*)) OR ((regenerative OR organic OR sustainab* OR agroeco*) NEAR/0 (agricultur* OR farm*)))	Organic/sustainable/regenerative agriculture, permaculture, or agroforestry
9	TS= (("integrated pest management" OR “landscape ecology” OR “landscape mosaic*” OR “landscape redesign”) AND (agricultur* OR farm* OR agroeco*))	Landscape-level management
10	#1 AND (#6 OR #7 OR #8 OR #9)	Combine search terms specific to nutrient management deep dive with the search terms for Agroecological Systems
11	#5 OR #10	Combine searches for Agroecological Practices and Agroecological Systems
12	TI=(USA OR US OR “United States” OR Canad* OR “North America*” OR Australia* OR “New Zealand” OR Europe* OR EU OR Austria* OR Belgium OR Belgian OR Bulgaria* OR Croatia* OR Cyprus OR Czech Republic OR Denmark OR Danish OR Estonia* OR Finland OR Finnish OR France OR French OR German* OR Greece OR Greek OR Hungar* OR Ireland OR Irish OR Ital* OR Latvia* OR Lithuania* OR Luxembourg OR Malta OR Netherlands OR Dutch OR Norw* OR Scandinavia* OR Poland OR Polish OR Portugal OR Portuguese OR Romania* OR Slovakia* OR Slovenia* OR Spain OR Spanish OR Swed* OR Switzerland OR Swiss OR “United Kingdom” OR UK OR Japan* OR Korea* OR Mediterranean)	High-income countries
13	TS=(agroecosystem* OR “agro-ecosystem*” OR “agroecological zone” OR “plastic mulch” OR “seed coating” OR soilless OR (wastewater NEAR/0 (municipal OR treatment)))	Agroecosystem, agroecological zones, and irrelevant agricultural practices
14	TI=(meta-analysis OR review OR opinion OR perspective)	Meta-analysis, reviews, and opinion articles
15	#11 NOT #12 NOT #13 NOT #14	Exclude studies in high-income countries, articles on irrelevant topics, and meta-analysis and review articles

Table A3 continued

16	TS=("climate change mitigation" OR "greenhouse gas*" OR "carbon sequestration" OR "carbon storage" OR "sequester carbon" OR "store carbon" OR "carbon sink" OR "soil organic carbon" OR "carbon storage" OR "emissions* abatement" OR "emission* reduction" OR "reduced emission*" OR "low-emission* development" OR "nitrous oxide" OR "carbon dioxide" OR "methane")	Climate change mitigation
17	TS=("climate change adaptation")	Climate change adaptation
18	TS=(productivity OR production OR yield OR co-product)	Productivity or yield
19	TS= ("crop diversity" OR "livestock diversity" OR "Ag* diversity" OR "genetic diversity" OR "Micro* diversity")	Agricultural diversity
20	TS=("Water regulation" OR "Water infiltration" OR "Nutrient regulation" OR "Soil water" OR "Soil nitrogen" OR "Soil aeration")	Water or nutrient regulation
21	TS= ((Resilience OR Recovery) NEAR/4 (Hurricane OR Storm OR Extreme))	Response to extreme event
22	TS=((health OR "organic matter" OR quality OR carbon OR aggregate* OR stability) NEAR/4 Soil)	Soil health
23	TS=((pollination OR pest OR arthropod* OR disease) NEAR (regulation OR service* OR management))	Pollination services or pest regulation
24	TS=(carbon NEAR (biomass OR tree OR shrub OR grass OR grassland OR pasture OR rangeland OR agroforest* OR root*))	Carbon sequestration in biomass
25	TS=((landscape* OR conservation) NEAR/4 (habitat OR diversity OR connectivity))	Landscapes or conservation
26	TS=("human capital" OR "traditional knowledge" OR "learning process*" OR "learning cycle*" OR "farm* learn*" OR "farmer exchange" OR "participatory extension" OR "citizen science" OR "living laborator*" OR "learning hub" OR "stakeholder engagement" OR "co-creation" OR "knowledge sharing")	Adaptation via learning processes
27	#15 AND (#16 OR #17 OR #18 OR #19 OR #20 OR #21 OR #22 OR #23 OR #24 OR #25 OR #26)	Refine search results by requiring that they include the specified climate change indicators
28	TS=((smallhold* OR largehold*) OR ((small-scale OR large-scale OR medium-scale) NEAR/10 (farm* OR agricultur*)))	Smallholders and medium- and large-scale agriculture
29	#27 AND #28	Refine search results by requiring that they reference farm size or agricultural scale
30	TS= (transition* OR scaling OR scale OR scale-up OR scale-out OR transform* OR adoption OR disadoption OR uptake OR innovation OR "institutional change" OR "organisational change" OR "systemic change" OR "social movement")	Scaling of agroecological practices or systems
31	TS= (drivers OR "enabling environment" OR "enabling conditions" OR barriers OR constraints OR obstacles)	Enabling conditions and barriers
32	TS= (intervention* OR development OR program* OR initiative* OR market* OR price* OR policy OR regulation OR governance OR subsidy OR "public-private" OR finance OR credit OR inputs OR "ecosystem payment*" OR "environmental payment*" OR "results-based payment*" OR "carbon market*" OR "ecosystem services market*" OR certification OR "land rights" OR tenure OR gender OR "food sovereignty" OR training OR "capacity building" OR "farmer field schools" OR education OR extension OR "co-learning" OR "innovation systems" OR participatory OR "action research" OR "seed systems" OR "consumer awareness" OR traceability OR collaboration OR "circular economy" OR stakeholder OR coordination OR organiz* OR "Value chain*")	Potential enabling conditions
33	#29 AND (#30 AND (#31 OR #32))	Refine search results by requiring that they reference scaling or barriers to scaling

Table A4. Search terms for pest and disease management deep dive. Note that TS refers to topic, TI refers to title.

Row	Search Terms	Description of Search Terms
1	TS=(((Pest OR Disease OR Arthropod*) AND (biopesticide* OR bioprotection OR "biological control" OR "natural pesticides" OR botanical* OR "beneficial arthropods" OR "Trap cropping" OR "Companion planting" OR "semiochemicals" OR biocontrol* OR "Push-pull" OR "Integrated crop")) AND (agricultur* OR Farm* OR forest*))	Only for Pest and Disease Management deep dive
2	TS=((intercrop* OR "crop association*" OR "doubled up" OR "doubled-up" OR "legume diver*" OR "rotat* diver*" OR "mixed crop*" OR "mixed cultivar*" OR "cover crop*" OR "green manure" OR "living cover") AND (agricultur* OR farm* OR agroeco*))	Cropping practices
3	TS= ((biofertili* OR "organic fertili*" OR manur* OR compost* OR mulch* OR "crop residue*" OR biopesticide* OR bioprotection OR "biological control" OR biocontrol*) AND (agricultur* OR farm* OR agroeco*))	Soil amendments and pest management
4	TS= (("perennial grain*" OR "push-pull" OR "recycl* nutrient*" OR "integrated crop" OR "integrated soil" OR "couple* carbon" OR "tighten nutrient" OR "nutrient budget") AND (agricultur* OR farm* OR agroeco*))	Pest management, nutrient recycling, and diversification
5	#1 AND (#2 OR #3 OR #4)	Combine search terms specific to the pest management deep dive with the search terms for Agroecological Practices
6	TS=((Pest OR Disease OR Arthropods) AND (agricultur* OR Farm* OR forest*))	Only for Pest and Disease Management deep dive
7	TS=(("crop livestock system" OR "integrated crop livestock" OR "crop-livestock" OR "agro-sylvo-pastoral" OR "sylvopastoral" OR "rotational grazing" OR diversif* OR "nutrient cycl*" OR "crop interaction" OR "pest-crop interaction" OR ecolog*) AND (agriculture OR farm* OR agroeco*))	Crop-livestock integration
8	TS=(("farmer participatory" OR "action research") AND (agriculture OR farm* OR agroeco*))	Participatory action research
9	TS=((("*ecologic* intensification" OR "low input" OR permaculture OR holistic OR "integrated organic" OR "certified organic" OR agroforest*) AND (agriculture OR farm* OR agroeco*)) OR ((regenerative OR organic OR sustainab* OR agroeco*) NEAR/0 (agriculture OR farm*)))	Organic/sustainable/regenerative agriculture, permaculture, or agroforestry
10	TS= (("integrated pest management" OR "landscape ecology" OR "landscape mosaic*" OR "landscape redesign") AND (agriculture OR farm* OR agroeco*))	Landscape-level management
11	#6 AND (#7 OR #8 OR #9 OR #10)	Combine search terms specific to pest management deep dive with the search terms for Agroecological Systems
12	#5 OR #11	Combine searches for Agroecological Practices and Agroecological Systems
13	TI=(USA OR US OR "United States" OR Canad* OR "North America*" OR Australia* OR "New Zealand" OR Europe* OR EU OR Austria* OR Belgium OR Belgian OR Bulgaria* OR Croatia* OR Cyprus OR Czech Republic OR Denmark OR Danish OR Estonia* OR Finland OR Finnish OR France OR French OR German* OR Greece OR Greek OR Hungar* OR Ireland OR Irish OR Ital* OR Latvia* OR Lithuania* OR Luxembourg OR Malta OR Netherlands OR Dutch OR Norw* OR Scandinavia* OR Poland OR Polish OR Portugal OR Portuguese OR Romania* OR Slovakia* OR Slovenia* OR Spain OR Spanish OR Swed* OR Switzerland OR Swiss OR "United Kingdom" OR UK OR Japan* OR Korea* OR Mediterranean)	High-income countries
14	TS=(agroecosystem* OR "agro-ecosystem*" OR "agroecological zone" OR "plastic mulch" OR "seed coating" OR soilless OR (wastewater NEAR/0 (municipal OR treatment)))	Agroecosystem, agroecological zones, and irrelevant agricultural practices
15	TI=(meta-analysis OR review OR opinion OR perspective)	Meta-analysis, reviews, and opinion articles
16	#12 NOT #13 NOT #14 NOT #15	Exclude studies in high-income countries, articles on irrelevant topics, and meta-analysis and review articles

Table A4 continued

17	TS=("climate change mitigation" OR "greenhouse gas*" OR "carbon sequestration" OR "carbon storage" OR "sequester carbon" OR "store carbon" OR "carbon sink" OR "soil organic carbon" OR "carbon storage" OR "emissions* abatement" OR "emission* reduction" OR "reduced emission*" OR "low-emission* development" OR "nitrous oxide" OR "carbon dioxide" OR "methane")	Climate change mitigation
18	TS=("climate change adaptation")	Climate change adaptation
19	TS=(productivity OR production OR yield OR co-product)	Productivity or yield
20	TS= ("crop diversity" OR "livestock diversity" OR "Ag* diversity" OR "genetic diversity" OR "Micro* diversity")	Agricultural diversity
21	TS=("Water regulation" OR "Water infiltration" OR "Nutrient regulation" OR "Soil water" OR "Soil nitrogen" OR "Soil aeration")	Water or nutrient regulation
22	TS= ((Resilience OR Recovery) NEAR/4 (Hurricane OR Storm OR Extreme))	Response to extreme event
23	TS=((health OR "organic matter" OR quality OR carbon OR aggregate* OR stability) NEAR/4 Soil)	Soil health
24	TS=((pollination OR pest OR arthropod* OR disease) NEAR (regulation OR service* OR management))	Pollination services or pest regulation
25	TS=(carbon NEAR (biomass OR tree OR shrub OR grass OR grassland OR pasture OR rangeland OR agroforest* OR root*))	Carbon sequestration in biomass
26	TS=((landscape* OR conservation) NEAR/4 (habitat OR diversity OR connectivity))	Landscapes or conservation
27	TS=("human capital" OR "traditional knowledge" OR "learning process*" OR "learning cycle*" OR "farm* learn*" OR "farmer exchange" OR "participatory extension" OR "citizen science" OR "living laborator*" OR "learning hub" OR "stakeholder engagement" OR "co-creation" OR "knowledge sharing")	Adaptation via learning processes
28	#16 AND (#17 OR #18 OR #19 OR #20 OR #21 OR #22 OR #23 OR #24 OR #25 OR #26 OR #27)	Refine search results by requiring that they include the specified climate change indicators
29	TS=((smallhold* OR largehold*) OR ((small-scale OR large-scale OR medium-scale) NEAR/10 (farm* OR agricultur*)))	Smallholders and medium- and large-scale agriculture
30	#28 AND #29	Refine search results by requiring that they reference farm size or agricultural scale
31	TS= (transition* OR scaling OR scale OR scale-up OR scale-out OR transform* OR adoption OR disadoption OR uptake OR innovation OR "institutional change" OR "organisational change" OR "systemic change" OR "social movement")	Scaling of agroecological practices or systems
32	TS= (drivers OR "enabling environment" OR "enabling conditions" OR barriers OR constraints OR obstacles)	Enabling conditions and barriers
33	TS= (intervention* OR development OR program* OR initiative* OR market* OR price* OR policy OR regulation OR governance OR subsidy OR "public-private" OR finance OR credit OR inputs OR "ecosystem payment*" OR "environmental payment*" OR "results-based payment*" OR "carbon market*" OR "ecosystem services market*" OR certification OR "land rights" OR tenure OR gender OR "food sovereignty" OR training OR "capacity building" OR "farmer field schools" OR education OR extension OR "co-learning" OR "innovation systems" OR participatory OR "action research" OR "seed systems" OR "consumer awareness" OR traceability OR collaboration OR "circular economy" OR stakeholder OR coordination OR organiz* OR "Value chain*")	Potential enabling conditions
34	#30 AND (#31 AND (#32 OR #33))	Refine search results by requiring that they reference scaling or barriers to scaling

4. Interview methods and results

A. Questionnaire: Development programmes and scaling up agroecological approaches in low- and middle-income countries

January 2021

The purpose of this questionnaire is to identify programming approaches and the conditions under which interventions have led to agroecological impacts and transitions at large scales.
We also want to understand the extent to which current approaches for scaling up agroecology conform to major agricultural development programming efforts (international and national).
Name of respondent..
Note taker.. Date..............................

1. Does your organisation have explicit programmes to support agroecological approaches (using this term) in low- or middle- income countries? Y/N

2. If yes, brief description of programme:

3. Does your organisation support any of the following elements of agroecological approaches in low- or middle- income countries? Y/N

Rate (0 to 5) for each element

1. DIVERSITY. Diversification is key to agroecological transitions to ensure food security and nutrition while conserving, protecting and enhancing natural resources.

2. CO-CREATION AND SHARING OF KNOWLEDGE. Agricultural innovations respond better to local challenges when they are co-created through participatory processes.

3. SYNERGIES. Building synergies enhances key functions across food systems, supporting production and multiple ecosystem services.

4. EFFICIENCY. Innovative agroecological practices produce more using less external resources.

5. RECYCLING. More recycling means agricultural production with lower economic and environmental costs.

6. RESILIENCE. Enhanced resilience of people, communities and ecosystems is key to sustainable food and agricultural systems.

7. HUMAN AND SOCIAL VALUES. Protecting and improving rural livelihoods, equity and social well-being is essential for sustainable food and agricultural systems.

8. CULTURE AND FOOD TRADITIONS. By supporting healthy, diversified and culturally appropriate diets, agroecology contributes to food security and nutrition while maintaining the health of ecosystems.

9. RESPONSIBLE GOVERNANCE. Sustainable food and agriculture requires responsible and effective governance mechanisms at different scales – from local to national to global.

10. CIRCULAR AND SOLIDARITY ECONOMY. Circular and solidarity economies that reconnect producers and consumers provide innovative solutions for living within our planetary boundaries while ensuring the social foundation for inclusive and sustainable development.

4. Identify other practices/interventions that your organisation has supported that you would consider agroecological.

5. Have you been able to implement any of these elements/practices/interventions at large scales, for example more than 100,000 farmers or 100,000 ha? Y/N

6. What are the most important drivers and enabling conditions or barriers for supporting agroecological transitions for outcomes at large scales in your experience? Check all that apply and indicate whether they have been primarily an E (enabling condition) or B (barrier)

A. Policies and incentives

1. ___ E/B National policy
2. ___ E/B Finance, credit
3. ___ E/B Corporate or government standards for agroecology
4. ___ E/B Markets and consumer demand (e.g., premium prices)
5. ___ E/B Farm-level economic costs and benefits: Costs of implementation, employment
6. ___ E/B Non-income related benefits (e.g., ecosystem services)
7. ___ E/B Potential trade-offs between food security and environmental goals
8. ___ E/B Political sensitivity of regulating farmers and the private sector
9. ___ E/B Other

B. Technical options, learning, innovation

1. ___ E/B Technical advisories, farmer-to farmer knowledge sharing; co-learning in practice, participatory research-action, bottom-up approaches .
2. ___ E/B Research, education and extension systems do not sufficiently respond to the needs of agroecology.
3. ___ E/B Communication and digital technologies
4. ___ E/B Other

C. Actors' roles and interests

1. ___ E/B Level of farmer decision-making autonomy - burgeoning
2. ___ E/B Role of civil society organisations and partnerships: farmer-researcher, farmer-consumer, farmers' organisations, women's organisations, youth organisations.
3. ___ E/B Institutional procurement of agroecological products. Hospitals, schools, military
4. ___ E/B Other

7. Did scaling of agroecological approaches involve significantly different conditions than scaling of conventional approaches? Y/N If yes, what was different? How would you compare the cost-effectiveness?

8. If systems-based approaches have been used, how would you compare system-based agroecological approaches to single practice-based approaches in terms of effectiveness for climate change adaptation and mitigation?

9. Did agroecological approaches confer additional benefits that matter to climate change adaptation and mitigation? Y/N.

If yes, what were the most important benefits?

10. Do you have a strategy for supporting agroecological transitions? Y/N. (OPTIONAL)

11. Knowledge gaps that need addressing, final comments or notes.

B. Interview respondents

Table A5. List of organisations supporting or implementing on-the-ground agricultural development who responded to the interview

Name	Type of organisations	Contact
National Research Institute for Agriculture, Food and Environment (INRAE), France	Government	Christian Huyge, Scientific Director for Agriculture
Kenya Agricultural and Livestock Research Organisation (KALRO)	Government	Michael Okoti, Director in Charge of Climate Change
Digital Green (East Africa)	NGO - Africa	Alesha Miller, Vice President of Strategy & Partnerships and Kebede Ayele, Country Director of Ethiopia
AP Community-Managed Natural Farming, Rythu Sadhikara Samstha, India	NGO - Asia	Vijay Kumar, Executive Vice Chairman
International Institute for Rural Reconstruction (IIRR)	NGO - Asia	Julian Gonzalez, Senior Advisor
Punjab Farmers and Farm Workers Commission	Farmer organisation - Asia	Ajay Vir Jakhar, Chairman, Punjab Farmers and Farm Workers Commission
Alliance for Food Sovereignty in Africa (AFSA)	Farmer organisation- Africa	Michael Farrelly, Programme Officer
Community Development and Knowledge Management for the Satoyama Initiative (COMDEKS), United Nations Development Programme (UNDP) and Global Environment Facility (GEF)-Small Grants Program	Intergovernmental organisation	Diana Salvemini, UNDP Global Coordinator for the SGP Upgraded Country Programmes Nick Remple, UNDP Global Advisor, Community-Based Landscape Management
McKnight Foundation's Collaborative Crop Research Programme (W Africa)	Donor	Batamaka Somé, Regional Representative for West Africa
US Agency for International Development (USAID)	Donor	Jerry Glover, Deputy Director for USAID's Center for Agriculture
Foreign, Commonwealth and Development Office (FCDO)	Donor	Alan Tollervey, Senior Agriculture and Livelihoods Adviser; Giles Henley Livelihoods and Climate Smart Agriculture Adviser, Joanna Francis, Livelihoods Advisor
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)	Donor	Stephanie Heiland, Head of Programme for Climate Smart Livestock Systems

ANNEX II. DESCRIPTIVE STATISTICS FOR NUTRIENT MANAGEMENT AND PEST AND DISEASE PAPERS REVIEWED

Table A6. Descriptive summary statistics for pest and nutrient management papers reviewed

Feature		Nutrient Management		Pest and Disease Management	
		Practices	System	Practices	System
Geographic scope†	Low	41	25	15	29
	Medium	10	6	6	5
	High	5	3	2	5
	Not specified	0	0	0	1
	Total	56	34	23	40
Continent†	Africa	46	21	16	30
	Asia	6	9	1	4
	Latin America	3	2	0	1
	Multiple	1	2	6	5
	Total	56	34	23	40
Farm size†	Small	46	27	17	20
	Medium	0	0	3	11
	Large	0	1	2	5
	Mix	3	2	0	2
	Not specified	7	4	1	2
	Total	56	34	23	40
Study methods	Experiment	25	7	5	10
	Survey	8	4	10	17
	Modelling	7	7	0	0
	Secondary data	1	2	0	2
	Mixed methods	14	8	6	5
	Other	1	1	0	0
	Total	56	29	21	34
Data type	Empirical data	42	19	18	30
	Modelled data	13	9	3	4
	Total	55	28	21	34
Economic analysis	Reported in study	17	13	10	19
	Not reported in study	39	16	11	15
	Total	56	29	21	34
Climate change adaptation indicators	Productivity	45	18	11	28
	Agricultural diversity	24	10	10	15
	Water & nutrient regulation	22	10	3	6
	Soil health	27	14	5	7
	Pollination services & pest regulation	6	1	21	32
	Landscapes and conservation	0	2	4	5
	Response to extreme events	3	2	1	1
	Total	127	57	55	94

Table A6 continued

Climate change mitigation indicators	Greenhouse gas emissions	3	3	0	0
	Carbon sequestration in soil	5	6	0	1
	Carbon sequestration in biomass	1	2	0	0
	Total	9	11	0	1
Local adaptation	Local knowledge	13	15	5	1
	Education/Extension	3	2	8	17
	Altering technology by context	9	4	0	1
	Farmer organisation	0	1	0	1
	Total	25	22	13	20
Scaling conditions or barriers	Reported in study	25	12	11	25
	Not reported in study	31	17	10	9
	Total	56	29	21	34

†Includes framework papers

ANNEX III. ADVISORY GROUP MEMBERS

Table A7. Name and corresponding organisation of donor advisory group members and reviewers

Name	Organisation
Donor advisors	
Christian Witt	Bill and Melinda Gates Foundation (BMGF)
James Birch	Bill and Melinda Gates Foundation (BMGF)
Anna De Palma	Foreign, Commonwealth and Development Office (FCDO)
Giles Henley	Foreign, Commonwealth and Development Office (FCDO)
Howard Standen	Foreign, Commonwealth and Development Office (FCDO)
Joanna Francis	Foreign, Commonwealth and Development Office (FCDO)
Rachel Lambert	Foreign, Commonwealth and Development Office (FCDO)
Stephanie Heiland	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)
Emily Weeks	United States Agency for International Development
Noel Gurwick	United States Agency for International Development
Donor reviewers	
Christophe Larose	European Commission Directorate-General for International Cooperation and Development (DG DEVCO)
Guy Faure	European Commission Directorate-General for International Cooperation and Development (DG DEVCO)
Daniel Frans van Gilst	Norwegian Agency for Development Cooperation (Norad)
Ueli Mauderli	Swiss Agency for Development and Cooperation (SDC)
Wijnand Van Ijssel	Ministry of Foreign Affairs, Netherlands
CCAFS reviewers	
Bruce Campbell	CGIAR Research Programme on Climate Change, Agriculture and Food Security (CCAFS)
Dhanush Dinesh	CGIAR Research Programme on Climate Change, Agriculture and Food Security (CCAFS)

Table A8. Name and corresponding organisation of technical advisory group members

Name	Organisation
Fabio Leippert	Biovision
Rikin Gandhi	Digital Green, Delhi, India
Jean-Francois Soussana	INRAE
Batamaka Somé	McKnight Foundation's Collaborative Crop Research Programme
Barbara Gemmil-Herren	Consultant and Prescott University
Boru Douthwaite	Selkie Consulting
Tom Tomich	University of California, Davis
Mercedes Bustamante	Universidade de Brasília

ANNEX IV. SYNTHESIS PAPERS SELECTED FOR REVIEW

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ANNEX V. FISHER'S EXACT TEST RESULTS

Fisher's Exact Tests

Hypothesis	Variables	p-value	Odds ratio	95% confidence Interval	Notes:
H1	Level ~ Local Adaptation	0.08302	0.5160231	0.2416459 1.0832633	Full dataset (n=138)
H2	Level ~ Mitigation indicators	0.8012	0.8193827	0.2672679 2.5110015	Full dataset (n=138)
H2	Level ~ Adaptation indicators	0.2502	0	0.000000 2.863285	
H2	Level ~ Pollination	0.02604	0.4572262	0.2153101 0.9573391	
H2	Level ~ Landscapes	0.3446	0.4533084	0.09255004 1.88811968	
H3	Level ~ Mitigation indicators	0.7802	1.329536	0.3830436 4.9654679	Dataset subset by productivity indicator (n=100)
H3	Level ~ Adaptation indicators	0.3705	0.280911	0.005525116 2.976367372	
H3	Level ~ Pollination	0.002327	0.2745083	0.1075547 0.6745804	
H3	Level ~ Landscapes	0.1773	0.2010404	0.003955226 2.130766959	
H4	Level ~ Co-learning	1	0.793376	0.1604009 3.7537840	Dataset subset by empirical papers with scaling indicators (n=48)
H4	Level ~ Stakeholder	0.3475	0.2237696	0.004239602 2.506852166	
H4	Level ~ Biophysical	0.234	Infinity	0.4242136 Infinity	
H4	Level ~ Farmer capacity	1	0.8131013	0.1838845 3.4908410	
H4	Level ~ Labour	0.193	2.931147	0.6595064 15.6336300	
H4	Level ~ Farm/household conditions	0.6085	0.3114731	0.00556607 4.22663593	
H4	Level ~ Policy	0.09715	0.1354278	0.002725668 1.271011908	
H4	Level ~ Lacking Institutions	1	0.8365112	0.2157926 3.1915156	
H1	Local adaptation ~ Ag diversity	0.8625	0.9273203	0.4426292 1.9474278	Full dataset (n=138)
H1	Local adaptation ~ Water/nutrient	0.5728	0.7800214	0.3503409 1.7426478	
H1	Local adaptation ~ Pollination	1	1.046775	0.4997601 2.2038662	

ANNEX VI.
RESULTS OF INTERVIEW WITH DONORS AND PROGRAMME IMPLEMENTATION EXPERTS

1. Level of prominence of the FAO 10 elements of agroecology in programme or policy design and implementation for 11 organisations on a scale of 1 to 5 (5 being the highest) per organisation.

Figure A3. Integration of FAO agroecology elements in programme or policy design and/or implementation for three NGOs.

Most frequently mentioned enabling conditions for scaling agroecology .

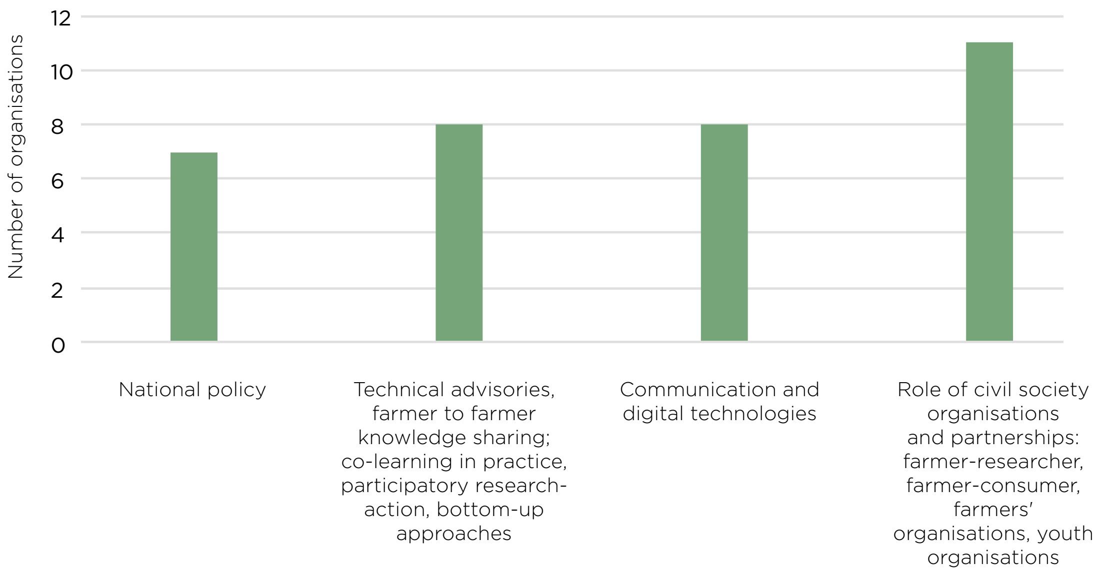

Figure A4. Interviewees answer to the question of scaling conditions of agroecological approaches compare to scaling of conventional approaches.

Table A9. Differences, similarities of scaling agroecological approaches compared to scaling conventional approaches according to interviewed respondents

	Yes, why?	**No, why?**
GIZ		Focus on capacity building, advisory to ministries and political institutions, and supporting financially. This role will remain the same in AE and non-AE. Quote: "If you want a farmer to do something differently you have a method of advising them, and this would be the same".
INRAE/ France	Conventional scaling leads to regional specialisation and this will be hard to break away from.	
FCDO	Complexity of applying disaggregated solutions at scale. How to make it sustainable financially when markets drive decisions? More significant role from the government is needed.	
IIRR	Easier to scale conventional agriculture because of the commodity approach, agroecology is intrinsically complex, leading to complexity in scaling.	
KALRO	Agroecology requires multidisciplinarity and stakeholder involvement in implementation, but also in the scientific arena alone. Values also need to change.	
FF India	The transition could only work if it is a community-led bottom-up approach and even then, it would be difficult.	
APCNF	Farmer-to-farmer extension system. Women self-help groups play a critical role in collective action and knowledge dissemination. Long-term handholding support to each farmer. We believe that a farmer requires 3 to 5 years to make the transition. Whole village approach.	
No yes or no answer, or not enough info on scaling AE, or both different and the same		
GEF	Agroecology is not yet at scale. In agroecology, knowledge sharing among people – peer to peer exchange is key. Peer to peer knowledge exchange process can be expensive; we're still in the early stages though. More research is needed to understand scaling potential.	
McKnight	Scaling a conventional approach is more top down. In agroecology civil society is committed and engaged, they also have a closer relationship with the researchers. Agroecology scaling can be more expensive in the short-term but can pay back in the long term; it will enable more assets in the next 5-10 years. Conventional is rapid in short term, but in 5-10 years you see the negative consequences.	
Digital Green	Video approach works well for agroecology because the visuals help with teaching complex things, but videos are also used for more conventional approaches.	
USAID	These questions come from a very industrialised agriculture perspective. The definition of conventional is relative. In some places, the conventional practices have been scaled up through conventional means but are still rather elegant agroecological systems.	

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Research supported by: