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DELIVERING CLIMATE CHANGE OUTCOMES WITH AGROECOLOGY IN LOW- AND MIDDLE-INCOME COUNTRIES: EVIDENCE AND ACTIONS NEEDED

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SUMMARY

Key Findings

- Substantial evidence exists for the impacts of agroecology in low- and middle-income countries (LMICs) on climate change adaptation.
    - **Farm diversification** had the strongest evidence for impacts on climate change adaptation.
- The evidence for agroecology's impact on mitigation in LMICs is modest and emphasises carbon sequestration in soil and biomass.
    - **Agroforestry** had the strongest body of evidence for impacts on mitigation.
- **Locally relevant solutions** produced through participatory processes and co-creation of knowledge with farmers improved climate change adaptation and mitigation.
- Knowledge gaps were found for agricultural climate change mitigation, resilience to extreme weather, and agroecology approaches involving livestock, landscape redesign and multi-scalar analysis.

Actions needed

- Assess the performance of agricultural development using an outcome-based approach based on agroecological principles and climate change adaptation and mitigation indicators to guide donor and national investment.
- Direct investment and scaling of practices where current evidence is strongest: agricultural diversification, agroforestry and local adaptation.
- Increase action on resilience to extreme weather and climate change mitigation outcomes in LMICs and build capacity of policy makers, scientists and institutions from the global South to work on these issues.
- Compare the cost-effectiveness and outcomes of agroecology approaches with other agricultural development interventions at multiple scales, including the valuation of environmental and social benefits to better evaluate alternative approaches to sustainable agriculture.

DOES AGROECOLOGY LEAD TO BETTER CLIMATE CHANGE OUTCOMES?

Food systems need to meet food security, nutrition and environmental goals, especially in a world with growing demand and a changing climate. There is now broad consensus on the need to transform current food systems towards more sustainable models. Agroecology is increasingly seen as a framework to transform food systems (HLPE 2019). A key question is: how far can agroecology meet the needs for climate change adaptation and mitigation in the food system, especially in low- and middle-income countries (LMICs) and at large scales?

To address this question, we conducted a 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 LMICs, and (ii) the programming approaches and conditions supporting large-scale transitions to agroecology.

Defining agroecology with precision is a challenge. The interpretation of agroecology in development has been divergent and contested, viewed variously as a set of practices, social movement or the science of sustainable agriculture (Bellword-Howard and Ripoll 2020, Wezel et al. 2020, Wezel et al. 2009). Moreover, differentiating agroecology from other forms of alternative agriculture for sustainability can be challenging due to vague or diverse definitions (Newton et al. 2020, Giller et al. 2021, Petersen and Snapp 2015). Box 1 provides examples of approaches to defining agroecology. Box 2 summarises major schemes for sustainable agriculture related to agroecology and climate change. All share the aim to reduce the negative impacts of agriculture, but approaches vary in their reliance on ecological processes, external inputs, whole system design, or emphasis on specific outcomes.

***Box 1.* Contemporary approaches to defining agroecology**
Ten elements of agroecology (FAO 2018): Diversity, co-creation and sharing of knowledge, synergies, efficiency, recycling, resilience, human and social values, culture and food traditions, responsible governance, circular and solidarity economy **Thirteen principles of agroecology** (HLPE 2019, also summarised here): recycling, input reduction, soil health, animal health, biodiversity, synergy, economic diversification, co-creation of knowledge, social values and diets, fairness, connectivity, land and natural resource governance, participation. Gliessman (2018): “Agroecology is the integration of research, education, action and change that brings sustainability to all parts of the food system: ecological, economic, and social”. It is transdisciplinary, participatory, action-oriented and “grounded in ecological thinking where a holistic, systems-level understanding of food system sustainability is required”.

For this analysis, we considered approaches as more agroecological to the extent they made use of ecological processes, supported increasing autonomy from external inputs, or enabled whole system change, rather than focusing on changing single practices (Sinclair et al. 2019, Leippert et al. 2020). We focused on the biophysical science and practice aspects of agroecology to assess impacts on climate change adaptation and mitigation, and on drivers and enabling conditions of farmer behaviour for the analysis of scaling.

We identified agroecology practices and systems guided by the United Nations' Food and Agriculture Organisation (FAO) 10 Elements of Agroecology and Gliessman's (2016) transitions framework. To distinguish agricultural approaches aligned with agroecology, we considered field, farm and landscape-level approaches that relied on enhanced ecological processes and services compared to business-as-usual agricultural development. Examples of agroecology approaches reviewed included diversifying crop production through cover crops, green manure and hosts for beneficial insects; managing organic nutrient sources; biopesticides; crop-livestock integration; agroforestry and organic farming.

Box 2. **Schemes for sustainable agriculture related to agroecology and climate change** (*adapted from* ***Petersen and Snapp 2015***)

- **Regenerative agriculture** seeks "to improve the health of soil or to restore highly degraded soil, which symbiotically enhances the quality of water, vegetation and land-productivity" (Rhodes 2017). The potential to enhance soil carbon has made these practices recently more prominent in climate discussions.
- **Sustainable intensification** is the production of more food on a sustainable basis with minimal use of additional land (Baulcombe et al. 2009). It creates "synergistic opportunities for the co-production of agricultural and natural capital outcomes (Pretty 2018). Often associated with an increased energy or fertilizer inputs and viewed as a means for sparing land, e.g., to avoid conversion of forests.
- **Ecological intensification** "harness(es) biological understanding to improve agricultural system performance, both in terms of productivity and environmental services" (Petersen and Snapp 2015).
- **Biodynamic farming** "organic farming techniques that improve soil health" in ways that "influence biological as well as metaphysical aspects of the farm". (Ponzio et al. 2013) Developed by Rudolf Steiner.
- **Organic agriculture is** a production system that sustains the health of soils, ecosystems, and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions rather than inputs with adverse effects. Organic agriculture combines tradition, innovation, and science to benefit the shared environment and promote fair relationships and good quality of life for all involved (IFOAM 2008).
- **Climate-smart agriculture** is "agriculture that sustainably increases productivity, enhances resilience (adaptation), reduces/removes GHGs (mitigation) where possible, and enhances achievement of national food security and development goals" (Lipper et al. 2014).

The evidence for the review was based on the published scientific literature and semi-structured interviews with representatives from agricultural development programmes. For the literature review, we identified 18 synthesis papers relevant to the impacts of agroecology on climate change adaptation and mitigation or the scaling of agroecology, representing over 10,212 studies. Only four of the 18 synthesis papers focused on LMICs, and only five others included at least 50% of the studies reviewed on LMICs, indicating the poor representation of LMICs for available syntheses in English. In addition, we conducted a systematic literature review of the primary evidence from LMICs for agroecological approaches and climate change outcomes related to nutrient management (15,674 articles) and pests and diseases (5,498 articles), resulting in a final selection of 138 papers representing about 20 agroecological practices. Of these papers, 71% represented data from Africa, 21% from Asia and 7% from Latin America, the latter suggesting the need for a similar review of the Spanish-language literature. One percent of the papers covered multiple regions. Seventy-eight percent of the papers addressed small farms, 9% addressed medium farms and 2% large farms. The full report is available online.

WHAT DOES THE EVIDENCE TELL US?

Climate change adaptation

Substantial evidence[1] exists for climate change adaptation in LMICs associated with practices and systems aligned with agroecology, e.g., farm diversification,[2] agroforestry and organic agriculture (Fig 1). 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 crop yield, pollination, pest control, nutrient cycling, water regulation and soil fertility.

We found in-depth evidence for the impacts of agroforestry and organic agriculture on adaptation. Agroforestry had a positive impact on biodiversity, water regulation, soil carbon, nitrogen and soil fertility and 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) (Smith et al. 2019).

Very little information was found about how agroecological approaches can improve resilience to extreme weather, which may be partly due to the challenges of studying responses to erratic, rare events and the need for modelling and global analytical approaches that were outside the scope of the studies reviewed.

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[1] The number of articles with primary evidence from LMICs for adaptation was 120 out of 138, based on indicators of productivity (100), diversity (58), water and nutrient regulation (41), soil health (52), and pollination services and pest regulation (59). The quality and relevance of the eight synthesis papers found were mostly medium to high.
Two synthesis papers were found for diversification (covering crop diversification, organic farming, intercropping, accessory crops, and agroforestry) with 98 and 99 high quality meta-analyses articles respectively.

[2] "Agricultural diversification is the intentional addition of functional biodiversity to cropping [and livestock] systems at multiple spatial and/or temporal scales, and it aims at regenerating biotic interactions underpinning provisioning [regulating and supporting] …ecosystem services. It embraces a variety of practices encompassing the management of crops, noncrop habitats, soil, and landscapes." Tamburini et al. 2020. *Brackets added by brief authors.*

Climate change mitigation

Evidence for impacts on mitigation is modest,[3] except for enhanced carbon sequestration in soil and biomass (Fig 1). The agroecological approach with the strongest body of evidence for impacts on climate change mitigation was tropical agroforestry, which was associated with sequestration of carbon in biomass and soil (medium evidence, high agreement) (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, predominantly from temperate regions and high income countries (Gattinger et al. 2012, Smith et al. 2019).

For example, Gattinger et al. (2012) reported that soil carbon stocks were higher by 3.50 ± 1.08 Mg C ha^{-1}, and soil carbon sequestration rates were higher by 0.45 ± 0.21 Mg C for pairwise comparisons of organic compared to non-organic farming, based on datasets from 74 studies. Nitrous oxide mitigation evidence was modest for tropical agriculture overall, and data on methane mitigation was very limited. Evidence from the global North suggests that reliance on organic nutrient sources and organic farming would likely avoid increased nitrous oxide emissions compared to the use of synthetic nitrogen fertiliser (medium evidence, medium agreement).

As the greenhouse gas (GHG) footprint of outcomes depends on where system boundaries are drawn, multi-scalar analysis is needed to capture flows of inputs and GHG impacts beyond the farm scale; for example, emissions associated with nutrient sources (e.g. industrial fertilizer production), land-use change or feed production (Connor 2018). The almost complete lack of data on tropical agriculture GHG emissions in agroecology exacerbates this research gap.

Box 3. Evidence used for the assessment

To assess the evidence for the impact of agroecology on climate change outcomes, we compiled information from two sources and triangulated findings. We selected:

1) high-quality, peer-reviewed review papers relevant to agroecology and climate change adaptation and mitigation impacts or the scaling of agroecology; and

2) primary evidence in scientific papers on approaches aligned with agroecology for (a) nutrient management and (b) integrated pest and disease management.

For the primary evidence papers, studies were only selected for analysis if they also indicated an 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. For these papers, we documented the presence of indicators as evidence for adaptation and mitigation impacts. This did not include whether impacts were positive or negative relative to a control.

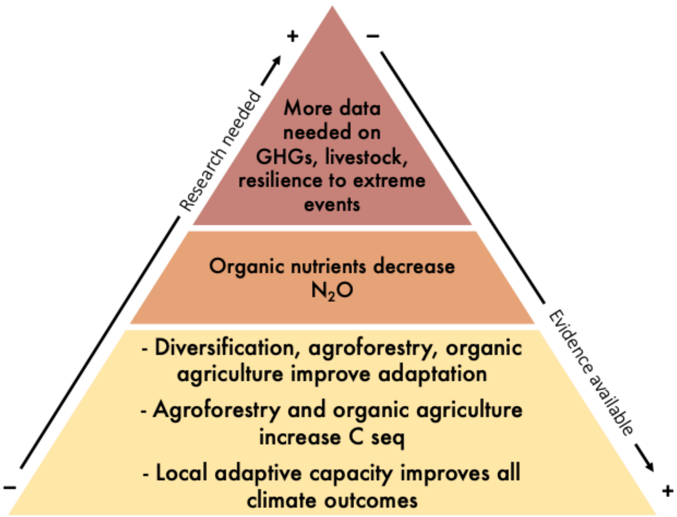
We also conducted semi-structured interviews with twelve organisations involved in agricultural development in LMICs, including several organisations implementing agroecology at large scales. These interviews aimed to explore the conditions and

[3] The number of articles with primary evidence from LMICs were limited: greenhouse gas emissions (6 articles), biomass carbon (4), soil carbon (12) from a total of 138 articles. The quality and relevance of the six synthesis papers found were low to medium. Two synthesis papers were found for agroforestry with 66 and 86 articles respectively.

constraints for scaling up agroecology, as experience with agroecology is still recent, and this information was not widely available in the scientific literature.

Evidence was evaluated based on the quality of evidence and level of agreement based on IPCC guidance for conducting syntheses (Mastrandrea et al. 2010). The evaluation was qualitative and relative. The strength of evidence was based on the degree of scientific robustness (statistical significance, sample size, use of systematic comparison, pairwise comparison, number of articles), relevance to agroecology, extent of geographic representativeness, relevance to LMICs, and overall quality or credibility of an article. The level of agreement was generally "high" if there were more than 100 articles with strong evidence, "medium" if 50-99 articles with strong evidence, or "low" if less than 50 articles with strong evidence, or in the case of interviews, where the majority of the respondents agreed.

Figure 1. **Evidence base for climate change adaptation and mitigation outcomes.**



Adaptive capacity

Evidence suggests that agroecology provides more climate change adaptation and mitigation than conventional, higher-input agricultural development in LMICs by emphasising locally relevant solutions, participatory processes and co-creation of knowledge as core values. Specifically, co-creation and sharing of knowledge supported farmers' capacity to adapt practices more successfully to local conditions (strong evidence, medium agreement). In addition, multiple lines of evidence showed that engaging with local knowledge through participatory and educational approaches effectively adapt technologies to local contexts and thereby deliver improved climate change adaptation and mitigation.

Most interview respondents agreed that system approaches that prioritised local adaptation provided 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".

Yields

Evidence for trade-offs between yields and climate change adaptation and mitigation exists, but was not systematically reported. There were win-win outcomes for yields and climate change mitigation associated with crop diversity and organic nutrient management. There was some evidence for modest trade-offs between yields and climate outcomes for organic farming and agroforestry. Diversification was associated with increased or maintained yields (although variable) compared to conventional agriculture (high evidence, high agreement). Conversely, 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, agroecological zone and soil type. For example, cocoa agroforestry produced lower cocoa yields, but higher overall yields from other crops in the system and improved climate change mitigation and adaptation (Niether et al. 2020). A review of agroforestry in sub-Saharan Africa found that agroforestry significantly increased yields and soil carbon (Kuyah et al. 2019).

Agroecological transitions for large-scale impacts

Evidence in the scientific literature relevant to scaling and enabling conditions of agroecology was poor, with only four relevant systematic reviews identified. The scientific robustness of the evidence was also mixed. Most reviews did not address agroecology at scale explicitly or compare the scaling conditions of agroecology and conventional agriculture. The literature review of primary evidence for agroecology approaches to nutrient and pest management reported many of the same interventions and enabling conditions as those observed for scaling conventional agriculture interventions. These included the need for farmer capacity building, use of markets, the necessity of involving government, the lack of cooperation between government offices of agriculture and offices of environment, and poor implementation of policies (low evidence, medium agreement).

Based on interviews with field programmes, common components of these programmes' efforts to bring agroecology to scale included farmer co-creation and exchange of knowledge, community-based, participatory methods, localised solutions and social organising. According to the literature, scaling agroecology systems, as opposed to practices, made more use of participatory and farmer-to-farmer processes and policy. Scaling also relied on market and policy measures that privileged local production. Agroecology's inherent complexity and knowledge intensity sometimes incurred higher costs and more time than conventional agriculture, but this also enabled effectiveness and sustained benefits over multiple years.

Modest evidence was also found regarding disadvantages and challenges that impede agroecological transitions. Of the 18 synthesis papers addressing agroecology and climate change impacts, only one explicitly addressed scaling (Cacho et al. 2018). Our review of the primary literature for nutrient and pest management yielded only 58 out of 138 articles on scaling-out processes, enabling conditions or barriers.

Critiques of agroecology have raised the issue of how to transition and reach large numbers of people. Compared to high-input sustainable intensification, agroecology can require more land to enable the use of ecosystem-based inputs and nutrient cycles (Connor 2018;

Schreinemachers et al. 2011). Co-design of options with farmers can be slower and more costly for facilitating organisations, compared to top-down technical solutions, but farmers are also more likely to benefit. The attention to local knowledge for adaptation is, in this regard, both a strength and a challenge. Supporting local knowledge also requires a change of mindset of local and international actors involved in agricultural research and development and additional investment. Using conventional economic analysis, agroecological approaches can be more expensive, and some require more labour inputs compared to high-input agriculture optimised for yields; although, long-term and ecosystem benefits can be higher. The yield trade-offs associated with some agroecology approaches are a disadvantage and may pose a substantial challenge to adoption, particularly for farmers with limited resources in LMICs. Because of these constraints, the private sector has lacked incentives to facilitate agroecological practices.

Gaps

There is a need for research, especially in LMICs, that compares agroecology against alternatives, including current practices in a locality and expected trajectories. More research is needed also for long-term studies on farms and at landscape scales in LMICs. A large data gap was found for agricultural GHG emissions and mitigation, with almost no evidence from LMICs. There were also evidence gaps for agroecology approaches involving livestock integration, landscape-scale redesign and for multi-scalar analysis.

Critiques of agroecology question the extent to which scaling agroecology may restrict farmers' options and become a poverty trap by not providing access to growth opportunities (Mugwanya 2019). Similarly, to what extent does agroecology empower and enable farmer organisation? There is generally a lack of data or scenarios showing the impacts of agroecological transitions on economic development. A better understanding of the political economy of development, including who wins and who loses, and evaluation of the short-term and long-term social and ecological benefits and trade-offs of agroecology compared with other agricultural development approaches could help inform development investment. The Transformative Partnership Platform (TPP) on agroecological approaches, aims to contribute to this area by evaluating the socioeconomic viability of agroecological practices across Africa.

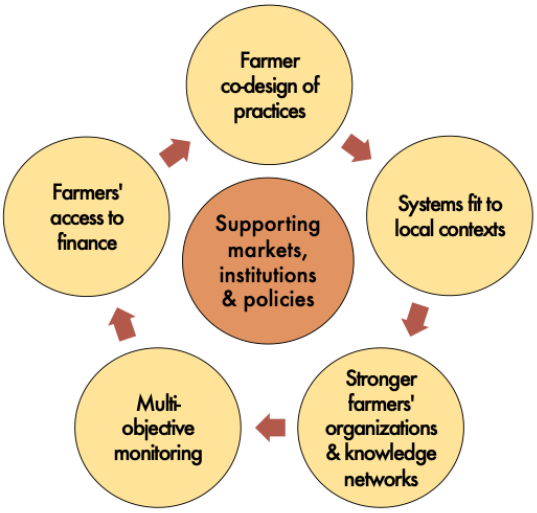
Donor investment

Recent reviews of funding for agroecology found that most investments at least partly support agroecological principles (Biovision and IPES Food 2020, CIDSE 2020). However, these analyses do not examine investments related to climate change adaptation or mitigation. The majority of agricultural investment (63%) is targeted at reinforcing or making minor adjustments to existing systems (sustainable intensification, separate funding mechanisms for agriculture and environment, performance measured mostly via yields) (Biovision and IPES Food 2020), despite calls for food system transformation (Steiner et al. 2020). Funding for agroecology remains a small proportion of major global agricultural development investment.

To improve investment in agroecology for climate change, long-term funding modalities, setting targets for outcomes that include environmental services and climate change outcomes – in addition to nutritional and livelihood and social outcomes – and seeking systemic change to building farmer capacities and incentives are needed (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 increase support for agroecology and climate change outcomes include (Fig 2):

- 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.
- Designing system approaches, including agroforestry, organic farming, 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 for 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.
- Providing institutional support for monitoring environmental services, assessing performance that considers more than productivity or profitability, using climate change mitigation and adaptation indicators. This is needed to inform policy across multiple dimensions and support annual reporting to the UN Framework Convention on Climate Change (UNFCCC).

Figure 2. **Programme elements for scaling up agroecology and climate change objectives**



WHAT ACTIONS NEED TO BE TAKEN?

Tackling climate change will require broad cooperation and diverse approaches. Implementing 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. Labels like agroecology can still be expedient for communication; the point is to spend less time debating what agroecology is.

We thus **recommend an outcome-based approach to guide donor investment and national policy, using an assessment of the performance of agricultural development that integrates agroecological principles and climate change adaptation and mitigation indicators**. 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. Attention to outcomes relevant to the sustainable development goals (SDGs) such as climate change resilience, environmental health, gender equity and social inclusion, soil health, biodiversity conservation, healthy diets and resource efficiency can provide common points of reference (Leippert et al. 2020).

A number of frameworks can be used to systematise monitoring of agroecology performance (Wezel et al. 2020; Kapgen and Roudart 2020), including FAO's Tools for Agroecological Performance Evaluation (TAPE) (Barrios et al. 2020, Mottet et al. 2020). The USAID-supported Sustainable Intensification Assessment Framework provides systematic approaches to outcome-based assessment and trade-off analysis (Grabowski et al. 2018).

Based on the strength of the evidence, **a second important action is to direct agricultural development investments to agricultural diversification, local adaptation and 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.

However, trends in agricultural development overall lean in the opposite direction, with widespread simplification of farms and cropping systems. Local adaptation can be promoted by supporting farmer innovation, co-learning and adaptation of innovations to local contexts. Top-down technology packages are often promoted rather than menus of farmer-co-designed options. Thus, diversification and local adaptation may require special attention at policy and program levels.

In many countries, local and national agroecology platforms already exist but can be strengthened to successfully use agroecology for climate change adaptation and mitigation in addition to the improvement of local livelihoods. Knowledge systems of agricultural producers need to be affirmed through networks of farmers and other stakeholders of the food systems to support co-design of climate-friendly practices. To support farmer investment in diversified farms, women and men farmers' access and control over land and other elements of agroecosystems will be key enabling conditions (FAO 2012).

The limited information for agroecological approaches' response to extreme weather events and GHG emissions is a matter of great concern. **A third action is to develop national strategies and action to enhance resilience to extreme weather events and climate change mitigation outcomes**. This should build on the experience of countries with experience of repeated extreme weather – such as the Philippines, Thailand, Haiti, and Honduras – to support strategies to embed planning for extreme weather events in national policies. There is an urgent need to build the capacity of policy makers, scientists and institutions from the global South to work on these issues.

A fourth action is public investment in research to improve analysis of agroecology relative to other agriculture development approaches at multiple spatial and time scales to better evaluate alternative approaches to sustainable agriculture**.** Assessment is required for food security, environment and other dimensions of sustainable development and the cost-effectiveness of different options in different contexts, including geographic regions. Assessment of cost-effectiveness should consider how to value environmental and social benefits and how assessment based on current policy contexts (e.g., subsidies) and short-time horizons might bias comparisons. Research includes comparative (alternatives versus conventional) and holistic (social, financial, environmental and agronomic) assessments. Reviews of French and Spanish-language literature would also enrich the foundation of evidence further, particularly for Latin America and West Africa.

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