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Editorial: Agroecological practices to enhance resilience of farming systems

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Editorial on the Research Topic
Agroecological practices to enhance resilience of farming systems

1 Introduction

Agroecology traces its origins to the early 20th century, when Basil Bensin coined the terms "agro-ecology" and "agro-ecological research" in 1930 to describe the application of ecological principles to agriculture (Bensin, 1930). Agroecology emerged as a formal discipline through the pioneering work of Tischler in the 1950s-60s, culminating in his seminal book *Agrarökologie* (Tischler, 1965). His research addressed pest management, soil biology, insect biocoenosis, and plant protection, emphasizing ecological processes across both cultivated and non-cultivated landscapes (Wezel et al., 2009). From the 1970s to 1990s, agroecology gained prominence as a response to the environmental and social consequences of the Green Revolution (Gliessman, 2013), with countries in Latin America becoming key hubs for farmer–scientist collaboration on sustainable alternatives (Altieri, 1996). Today, agroecology refers to either a scientific discipline, an agricultural practice, or a political and social movement (Wezel et al., 2009).

Climate change and the overexploitation of natural resources in conventional or industrial agriculture are compromising the sustainability of agroecosystems, undermining future food security, agricultural resilience, and planetary health (van Vuuren et al., 2025). The FAO's 10 Elements of Agroecology (FAO, 2018) and the HLPE's 13 Agroecological Principles (HLPE, 2019) are complementary frameworks developed to guide the transformation of food and agricultural systems toward sustainability and resilience, grounded in agroecological approaches. These frameworks translate ecological principles into practical strategies, emphasizing diversity, co-creation, resource efficiency, and equity, enabling farmers to enhance resilience, reduce external input reliance, and support local food systems.

Therefore, in contrast to conventional or industrial agriculture, agroecology offers a holistic framework that integrates ecological, social, and human dimensions across temporal and spatial scales (Wezel et al., 2020). By leveraging synergies among natural processes and stakeholder knowledge, agroecology enhances the adaptive capacity of farming systems and guides transitions toward sustainable and climate-resilient food systems.

This Research Topic addresses these challenges by presenting empirical and conceptual insights demonstrating the effectiveness of agroecological practices in building agroecosystem resilience and mitigating the impacts of climate change. The selected manuscripts from diverse geographic regions (Figure 1) converge around three major themes: (i) Multicriteria analysis and identification of research gaps to improve the implementation and scaling of agroecology practices; (ii) Crop diversification strategies that contribute to improved productivity, ecosystem services, and climate adaptability; (iii) Soil management and diversification approaches that restore soil health, support carbon storage, and improve nutrient cycling.

Collectively, these contributions underscore the interdisciplinary nature of agroecological research, demonstrating how progress in agroecology depends on the integration of agronomy, ecology, socioeconomics, and participatory governance.

2 Multicriteria analysis of agroecology

Multicriteria analyses and original studies have assessed the current state of agroecology and its potential to enhance system resilience. Altieri et al. highlighted the limits of agroecology adaptation under increasingly severe climate events, noting that smallholder practices like intercropping, agroforestry, mulching, and organic amendments improve drought resilience but may be insufficient under prolonged stress. They emphasized the need for strategies that sustain productivity during extended droughts, alongside tools to assess resilience, while acknowledging the importance of broader interventions such as watershed restoration and policy support.

von Cossel et al. synthesized meta-analyses on agroecology, focusing on crop diversification and soil management. Key practices included agroforestry, cover cropping, intercropping, mixed varieties and use of local varieties, as well as green manures, mulching, no-till, and organic inputs. Outcomes varied by site, reflecting complex ecological and socio-economic interactions. The authors proposed a systems-based approach integrating crop-livestock dynamics and circular economy principles. Further research and long-term monitoring should address crop and soil diversification jointly to enhance resilience and support farmer-oriented solutions.

Negri et al. compared agroecology responses in California and Italy, regions facing increased temperatures, erratic rainfall, and declining yields in specialty crops. Practices such as cover cropping, diversification, and precision irrigation can improve soil health and water use, but tailored strategies, policy support, and international cooperation were deemed critical for effective adaptation.

Agroecology transitions in Western Rwanda using longitudinal data from 150 farmers (1995–2015) were examined by Kuria et al. Policy shifts and land scarcity led to the loss of low-value crops, reducing diversity and increasing food insecurity in 83% of households. Though perennial crops buffered seasonal hunger, on-farm food self-sufficiency declined from 10.1 to 6.6 months. The study identified seven agroecology principles as key to resilience, underscoring the need for context-specific, inclusive policies grounded in local knowledge.

3 Crop diversification strategies

Here, annual grain legumes, annual and perennial cereals, and key agroecology practices were studied. In Tanzania, Lelei et al. evaluated integrated soil fertility management in degraded maize systems. Combining lime with mineral fertilizers, i.e., nitrogen (N), phosphorus and potassium, improved yields and soil quality, while

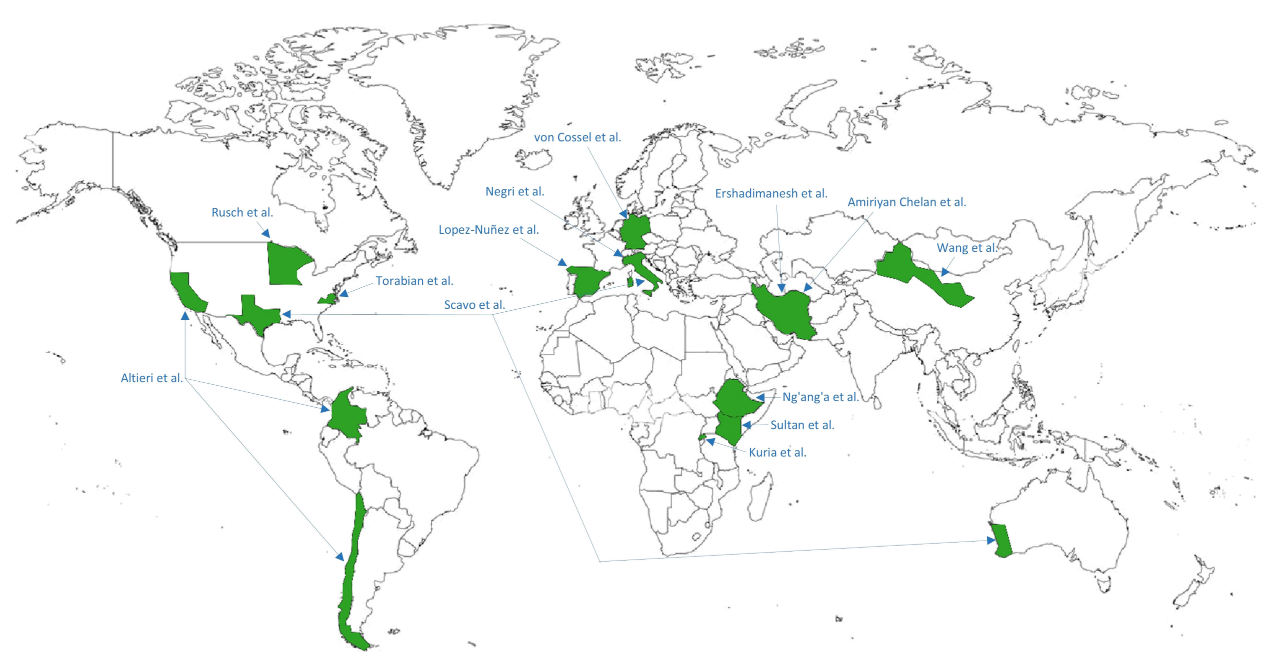

FIGURE 1
Distribution map of the published articles included in the Research Topic (created using ArcGIS software by Esri).

lime with manure proved more cost-effective and sustainable, supporting smallholder livelihoods.

Rusch et al. studied the perennial grass, intermediate wheatgrass (*Thinopyrum intermedium*), in Minnesota over four years. The dual-purpose grain-and-grazing system matched or surpassed the combined yields of grain and straw after year 2 and provided high-quality forage (protein: 140–150 g kg^{-1}). Though initial grain returns were lower, diversified forage income and peak productivity in year 3 suggest that delayed grazing could optimize profitability.

Ng'ang'a et al. assessed the profitability and risk of agroecology practices among wheat farmers in Ethiopia. A cost-benefit analysis showed certified seeds were most profitable, followed by optimized fertilizer use and drainage (net present value: 2531, 2371, 2099 US$ ha^{-1}, respectively). Despite favorable returns, adoption depends on social and behavioral factors, warranting further research to promote agroecology practices better.

At Virginia State University, varietal performance and planting date effects on faba bean were evaluated for rotation potential. Under current conditions, fall planting with specific varieties produced 58% more branches, double the grain yield, and heavier seeds than spring planting (Torabian et al.). Insight into nutrient components and crop succession is needed to optimize cropping systems, including faba bean.

Ershadimanesh et al. examined source–sink dynamics in bread wheat through defoliation treatments 'removal of the flag leaf' (RFL), 'removal of all leaves' (RAL), and 'removal of the upper half of the spikes' (RHS) under irrigated and rainfed conditions. Drought reduced grain weight per spike (18%) and yield (25%). Defoliation reduced grain weight by 6.7–12.3%, with RFL and RAL enhancing stem and spike remobilization. The RHS treatment showed stronger sinks in vegetative organs than grains but stimulated remobilization. Enhancing both photosynthetic capacity and sink strength is critical to improve yield.

4 Soil management strategies

Rhizobium bacteria, arbuscular mycorrhizal fungi (AMF), growth-promoting bacteria (GPB), mulching, and integrated fertilizers to enhance crop yield and soil health were studied.

In East Azarbaijan, Amiriyan Chelan et al. evaluated the effects of AMF, GPB, and chemical fertilizer on fenugreek intercropped with Moldavian balm. Intercropping (100:50 ratio) with AMF+GPB significantly improved oil yield, fatty acid content, and land equivalent ratio. The treatment also increased anthocyanins, flavonoids, mucilage, and linoleic acid by up to 15.2%, supporting its suitability for sustainable systems.

Scavo et al. assessed biological N fixation in five Mediterranean forage legumes using three rhizobia inoculants, i.e., Australian granular, Australian peat, and American peat, at standard and double doses. Australian granular performed best overall, while American peat was effective only at higher doses. Double-dose inoculation notably enhanced nodulation and N-fixation, highlighting the need for tailored legume–inoculant combinations to reduce fertilizer dependence.

Lopez-Nuñez et al. tested chitosan for managing soil fungi in persimmon plots under conventional and ecological systems. In pots, chitosan reduced soil pH, conductivity, and cation exchange capacity without affecting soil respiration. In the field, chitosan coacervates boosted the beneficial fungus *Purpureocillium* (50-fold) and suppressed pathogens like *Fusarium* (−50%) and *Alternaria* (−20%). Microbial network analysis showed enhanced roles for nematophagous fungi, affirming chitosan's contribution to soil health.

On the Loess Plateau, Wang et al. conducted a 3-year study on maize systems. High-density planting combined with fertilization and mulching increased yields and water use efficiency by 34–56% over basic farming practices. It furthermore outperformed controls in photosynthetic rate, leaf area index, chlorophyll content, and root growth, underscoring the value of integrated practices in semiarid agriculture.

Author contributions

DS: Conceptualization, Data curation, Project administration, Supervision, Visualization, Writing – original draft, Writing – review & editing. MC: Project administration, Validation, Visualization, Writing – review & editing. FG: Project administration, Supervision, Validation, Writing – review & editing.

Conflict of interest

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