Restoring Africa's Soils: A Meta-Analysis of Agroecological Practices and Their Impact on Soil Health

Dr Keiron Audain

Executive Summary

Introduction

Africa faces a severe soil degradation crisis, with the overuse of chemical fertilizers, monocropping, and continuous tillage being major contributors to this decline in soil fertility. This results in significant economic losses and diminished agricultural productivity. In response, agroecology offers a holistic approach to restoring soil health by integrating ecological principles, traditional knowledge, and modern science to create resilient farming systems. Agroecological practices have proven to improve soil fertility, enhance biodiversity, increase water retention, and boost climate resilience. Despite these benefits, the widespread adoption remains limited due to several challenges.

Objectives and Methodology

The objective of this meta-analysis was to evaluate the effect of agroecological practices on soil health across 11 African countries: Sierra Leone, Malawi, Zambia, Zimbabwe, South Africa, Uganda, Kenya, Tanzania, Burkina Faso, Senegal, and Togo. The analysis aimed to identify best practices, challenges, and policy recommendations for promoting soil health and sustainable agricultural systems through agroecology. The study involved a systematic review of 61 case studies sourced from the AFSA/HSHF database and academic literature. Data were extracted using a standardized form to capture key information on project objectives, practices, findings, and limitations. Qualitative data was collected through key informant interviews with experts from four of the target countries (Malawi, Tanzania, Uganda, and South Africa). Thematic analysis was used to identify key patterns and insights from the interview data, which were triangulated with the case study findings.

Key Findings

The findings highlighted the positive impact of agroecological practices on soil health and agricultural productivity. Practices including organic inputs, crop diversification, minimal tillage, and agroforestry, were reported to significantly improve soil health by contributing to better water retention, reduced erosion, and enhanced climate resilience. However, challenges such as limited access to organic inputs, insufficient policy support, and economic barriers were prevalent across countries.

<u>Agroecological practices</u>

Organic inputs such as compost, manure, bio-fertilizers, and biochar were the most commonly implemented agroecological practices, used in 36 of the case studies. These inputs were found to significantly improve soil fertility by increasing organic matter, enhancing microbial activity, and promoting nutrient cycling. In Tanzania, for example, the use of organic manure doubled maize yields from 1.3 to 2.6 tons per hectare, while also improving soil moisture retention and reducing erosion.

Agroforestry systems, implemented in 24 case studies, were highly effective in restoring degraded soils and improving water retention. Trees, particularly leguminous varieties, played a crucial role in nitrogen fixation and preventing soil erosion. In Kenya, agroforestry increased the resilience of farming systems by providing shade and wind protection, while simultaneously improving soil health and biodiversity.

Intercropping, practiced in 23 case studies, enhanced soil fertility through nitrogen fixation by leguminous plants and increased biodiversity, which helped reduce pest pressures. In Uganda, the integration of diverse crops such as maize and beans improved soil health, reduced reliance on chemical inputs, and boosted overall agricultural yields.

Water conservation practices such as ridges, pits, rainwater harvesting, and swales were critical in regions facing water scarcity. These methods, adopted in 21 case studies, helped improve soil moisture retention and reduced erosion, particularly in semi-arid regions like Tanzania and Zimbabwe. In Tanzania's Kilimanjaro region, the application of contour farming and mulching led to a significant increase in cereal yields and reduced soil erosion.

Socio-Economic and Environmental Impacts

Agroecological practices contributed to improved soil health and enhanced food security, livelihoods, and community resilience. Several case studies highlighted the broader social and economic benefits of adopting agroecology.

Agroecological practices contributed to enhanced food security in rural communities by improving soil fertility and boosting crop yields. In Zimbabwe, farmers practicing conservation agriculture reported a 72% increase in crop yields, while in Malawi, legume intercropping improved soil fertility and increased maize yields, contributing to more reliable food production.

Agroecological practices reduced input costs by minimizing the need for synthetic fertilizers and pesticides. Farmers were able to produce organic inputs such as compost and manure, which could be used on their farms or sold for additional income. In Zambia, the Bokashi Fertilizer Initiative significantly boosted maize yields while reducing reliance on chemical inputs, leading to increased household incomes.

Several projects focused on empowering women and marginalized communities by promoting agroecological practices that are inclusive and accessible. In Kenya, for example, women were trained to produce biofertilizers and organic manure, which improved soil health and generated income through local markets. Agroecological training programs also fostered greater community cohesion by encouraging collective action and shared knowledge.

Agroecological practices enhanced biodiversity, improved ecosystem services, and contributed to climate resilience. In Burkina Faso, the use of zai pits and rock dams helped restore degraded land, raised groundwater levels, and increased cereal yields. The integration of agroforestry and organic inputs further promoted ecosystem health, supporting the long-term sustainability of farming systems.

Challenges and Barriers to Adoption

Despite the positive outcomes associated with agroecological practices, several barriers hinder their widespread adoption across the target countries

Many agroecological practices require significant labor inputs, which can be a major barrier for smallholder farmers with limited resources. In Tanzania and Burkina Faso, the labor-intensive nature of soil conservation practices often discouraged farmers from fully adopting these methods, despite their long-term benefits.

The limited availability of extension services and technical assistance was a recurring challenge in many case studies. Government extension workers, often trained in conventional farming methods, lacked the knowledge and expertise to support farmers in transitioning to agroecological practices. This gap in technical support hindered the scaling of sustainable land management practices.

The high upfront costs associated with adopting agroecological practices, such as purchasing organic inputs or implementing water conservation infrastructure, were a significant barrier for many smallholder farmers. Additionally, the lack of access to premium markets for organic products limited the financial viability of agroecology for some farmers.

Many current agricultural policies favor conventional farming methods, particularly the use of chemical inputs, which are often subsidized by governments. These subsidies create a disincentive for farmers to adopt agroecological practices, as synthetic fertilizers and pesticides are more readily available and cheaper in the short term.

Policy Recommendations

To promote the adoption and scaling of agroecological practices across Africa, several key policy recommendations emerged from the findings:

Expand Access to Organic Inputs
Governments should invest in the development of organic input markets, including the production and distribution of bio-fertilizers, compost, and organic manure. Subsidies should be redirected from synthetic fertilizers toward supporting the use of organic inputs.

Strengthen Extension Services
Training programs for government extension workers should focus on agroecological practices to ensure that farmers receive the technical support they need to adopt sustainable land management methods. Additionally, farmer-to-farmer knowledge-sharing programs should be scaled up to enhance the dissemination of agroecological techniques.

Promote Agroecological Research and Infrastructure
Increased investment in agroecological research is needed to develop context-specific solutions for soil health improvement. Governments should also support the development of infrastructure for water conservation and soil management, particularly in regions facing climate challenges.

Facilitate Market Access for Agroecological Products
Governments should establish certification systems for organic and agroecological products to help farmers access premium markets. Developing local and regional markets for agroecological produce will enhance the economic viability of sustainable farming practices.

Conclusion

This study highlighted the importance of agroecological practices in improving soil health, enhancing resilience to climate change, and promoting sustainable agricultural systems across Africa. While these practices offer a viable solution to soil degradation and food insecurity, their adoption requires considerable policy support, investment in infrastructure, and farmer training. Governments, NGOs, and international organizations must collaborate to scale up agroecological practices and address the challenges faced by smallholder farmers in adopting these methods. Ultimately, agroecology represents a pathway toward achieving long-term sustainability and food security for future generations across Africa.

Introduction

Modern science and traditional knowledge consider healthy soil to be instrumental in maintaining both planetary and human well-being, as soil serves as the foundation for food production and ecosystem balance. Healthy soil sustains agricultural productivity as well as plays a significant role in carbon sequestration, water filtration, and supporting biodiversity (Zenda & Rudolph, 2024).

However, industrialized agriculture largely overlooks these realities, as a large number of conventional farming practices contribute to soil degradation and nutrient depletion, due to the loss of organic matter. These unsustainable practices range from monocropping, over-use of chemical inputs, to continuous tillage, all of which lead to a decline in soil fertility. Continuous tillage increases soil erosion, compacts the soil, and reduces soil microbial diversity. In addition, excessive use of chemical fertilizers and pesticides alters the soil's chemical composition, which adversely affects its ability to regenerate and sustain biological functions (Dainese et al. 2019). Such negative impacts are most notably observed in low to middle-income countries that primarily rely on smallholder farming to maintain their livelihoods and food supply. It has been estimated that approximately 65% of arable land in Sub-Saharan Africa is considered too degraded to support food production. This reportedly leads to an annual loss to farmers of roughly US$68 million (Zingore et al. 2015). Such an alarming statistic should indeed stress the urgency that African governments need to place on addressing soil health.

Agroecology places a focus on ecological principles and traditional knowledge to promote alternative farming practices that have proven essential for maintaining soil health. Key agroecological practices include crop diversification, organic matter management, minimal tillage, agroforestry, and the integration of livestock into farming systems. Such practices have been shown to improve soil fertility and structure, increase biological activity, boost water retention, as well as contributes to climate resilience, food sovereignty, and overall environmental sustainability.

The widespread adoption of agroecological practices across Africa continues to face multiple challenges. For instance, farmers often lack the necessary information and support to effective implementation (Akanmu et al. 2023). Many current agricultural policies also favor conventional farming methods that promote chemical inputs, thus creating policy barriers to agroecological adoption. Meanwhile, the pool of research literature in support of agroecology has been growing steadily in recent years. Several studies have highlighted the benefits of agroecological practices on soil fertility, crop yields, and climate resilience. For example, research has shown that agroforestry, cover cropping, and organic fertilization can significantly enhance soil organic matter, reduce erosion, and improve water retention (Souissi et al. 2024). Yet despite such findings, considerable research gaps still exist. In addition, much of the current research remains fragmented, with little contextual understanding of how specific practices can be scaled up across different countries and regions. There is also limited evidence on the long-term impacts of such practices on soil health, particularly in terms of their economic viability and social acceptability among smallholder farmers.

The purpose of this meta-analysis is to systematically review available case studies relating to the implementation of agroecological projects across 11 target countries in Africa, with the aim of addressing existing research gaps. The analysis aims to provide an assessment of the effectiveness of these practices across different contexts, identify the factors that contribute to their success or failure, and explore the long-term sustainability of agroecological approaches in African farming systems. The findings will be used to inform policy documents that advocate for the adoption and scaling up of agroecological practices across Africa.

Objectives

The main objective is to explore the effects of agroecological practices on soil health in 11 target countries in Sub-Saharan Africa.

Research Questions

1. What are the most beneficial agroecological practices for improving soil health in different African contexts?

2. What are the medium to long-term socio-economic and environmental benefits of adopting agroecological practices on smallholder farms?

3. What are the main challenges farmers face in adopting these practices?

4. What policy recommendations can be made based on evidence from existing agroecological practices and outcomes across 11 African countries?

Methodology

Search Strategy

Case studies were primarily sourced from the AFSA/HSHF project database and information was entered into a data extraction form. Additional sources included relevant peer-reviewed articles and university dissertations identified through targeted searches in academic databases PubMed, Scopus, Web of Science, and Google Scholar. Search terms used included combinations of keywords such as "agroecology," "soil health," "crop yield," "Africa," and "case study." The search criteria resulted in a collection of eight case studies that showcased the impact of agroecological practices on soil health and crop yield in the target countries. The data extraction form allowed for an indepth analysis of the information gathered, providing insights into the benefits of adopting agroecological practices.

Inclusion and Exclusion Criteria

Case studies were included based on agroecological projects carried out in any of the 11 target countries: Sierra Leone, Malawi, Zambia, Zimbabwe, South Africa, Uganda, Kenya, Tanzania, Burkina Faso, Senegal, and Togo. These provided quantitative data on soil health metrics, crop yields, and socioeconomic outcomes. Case studies published in English or French were also included, ensuring representation of current agroecological practices in the target countries.

Case studies that did not focus on agroecological practices or were outside the geographic scope of the target countries were not included. Also, documents that did not provide any detail or data on relevant outcomes (e.g., soil health, yields) were omitted. Articles published in languages other than English or French were also excluded, as were opinion pieces, editorials, and other literature that did not contribute empirical data.

The final selection consisted of a total of 61 studies that met the predetermined criteria. These articles provided an overview of the benefits of agroecological practices in the target countries, highlighting the impacts on soil health, yields, and overall sustainability.

Data Extraction

Data extraction was conducted using a standardized Excel spreadsheet form designed to capture essential information from each included study. Key variables of interest included project objectives, methods practiced, key findings, impact metrics, project limitations, and sustainability efforts. Details on geographic location, year project started, and project lead were also extracted. The extracted data were then entered into a data extraction spreadsheet for further analysis. This data extraction process ensured that all relevant information was captured accurately and consistently across all studies. Through the use of key variables such as project objectives and limitations, the researcher was able to gain a comprehensive understanding of each project's scope and impact. The data extraction spreadsheet allowed for comparison and analysis of the collected data, facilitating the identification of trends and patterns in the research. Bth Vancouver and Harvard in-text referencing were used to distinguish between the case studies and the other references (e.g. peer-reviewed journals). Vancouver referencing were used for the case studies and Harvard was used for the other references.

Data Analysis

Frequency distributions were used to assess the number of case studies in each target country, and prevalence of various agroecological practices across the case studies. Subgroup analyses were also conducted to explore variations in outcomes based on geographic location, and type of agroecological practice. These analyses helped identify factors that influenced the effectiveness of agroecological interventions. The results provided insights into the benefits of agroecology in different regions and contexts.

Key Informant Interviews

Participants for the Key Informant Interviews were chosen based on their relevance to the Healthy Soils Healthy Foods (HSHF) initiative and their expertise in areas such as soil health, agroecology, and policy development in Africa. The participants were drawn from the target countries, and the pool was identified through AFSA's network, previous collaborations, and key institutions involved in soil health and agroecology in Africa.

The interview process was conducted using a semi-structured format, which allowed for flexibility while ensuring that core topics related to soil health, agroecology, and relevant policies were consistently addressed. Interviews were scheduled based on participant availability and were conducted virtually using Zoom and Microsoft Teams. A semi-structured interview guide was developed, covering questions on soil health challenges, agroecological practices, policy environments, and market opportunities. Each interview lasted between 30 minutes to an hour, during which both audio recordings and detailed notes were taken with the participants' consent. This approach ensured that all relevant information, including non-verbal cues and contextual details, were captured.

Data collection focused on key themes such as agroecological practices, challenges to soil health, the effectiveness of policies, and market access for organic inputs. The interviews also provided contextual insights into how local conditions influence soil health and agroecology practices in different countries, along with participant recommendations for policy improvements.

Data analysis was conducted using thematic analysis, a qualitative method for identifying, analyzing, and reporting patterns within the interview data. This process was divided into two stages: manual coding followed by the use of NVivo software to support and refine the analysis. Interview recordings were automatically transcribed using AI software (Otter.ai, Microsoft Teams), then reviewed thoroughly to correct errors and ensure a clear understanding of the data. The manual coding process involved reading through the transcripts line by line and assigning codes to specific segments of the data based on the themes emerging from the discussions. These initial codes were then organized into broader themes that captured significant patterns related to soil health, agroecological practices, and policy challenges.

Following the manual coding, NVivo software was used to further analyze and organize the data. The transcribed interviews and manual codes were imported into NVivo, which enabled more detailed analysis and allowed for the identification of patterns that might not have been evident during manual coding. The software's query functions were used to explore relationships between different themes and to quantify the frequency with which certain themes appeared across the data.

Results

Study Characteristics

The case studies included in this meta-analysis spanned across the 11 target African countries, with a representation of diverse agroecological practices and interventions. From the 63 documents in the AFSA project database, a total of 53 documents met the inclusion criteria. An additional eight were sourced from academic databases, for a total of 61 case studies. The projects analyzed were generally community-driven and implemented by local and international NGOs, with varying levels of governmental support. The studies employed a variety of designs, including case studies, participatory research, and field trials. The participants were primarily smallholder farmers, often organized into cooperatives or community groups. A significant focus was placed on women and marginalized communities, with several projects specifically aimed at empowering these groups through sustainable agricultural practices. The distribution of case studies was primarily concentrated in Kenya with 13 cases, followed by Zimbabwe with 10 and Tanzania with seven (See Table 1).

Table 1: Distribution of case studies across the 11 target countries

Country	Number of Case Studies
Zimbabwe	10
Tanzania	7
Kenya	13
Uganda	5
Burkina Faso	6
South Africa	4
Malawi	5
Togo	3
Senegal	4
Zambia	3
Sierra Leone	1
Total	61

Organic inputs, ranging from green and animal manure, bokashi and other bio-fertilizers, and bio-char were the most commonly used agroecological practices, appearing in 36 case studies from all 11 target countries. This was followed by agroforestry practices (24), intercropping and companion planting (23), and water conservation practices, including ridges, pits, rainwater harvesting, and swales (21) (See Table 2). As multiple practices were typically applied in unison, the observed benefits were not attributed to any specific practice.

Table 2: Distribution of agroecological practices across case studies in the target countries

Agroecological Practice	Case Studies	Countries
organic inputs(e.g. green/cattle manure, bio-fertilizer, biochar)	36	Tanzania, South Africa, Kenya, Zambia, Uganda, Zimbabwe, Togo, Malawi, Burkina Faso, Senegal, Sierra Leone
Composting	16	South Africa, Kenya, Zimbabwe, Senegal, Burkina Faso, Malawi, Togo, Sierra Leone, Tanzania
Minimal tillage	7	South Africa, Kenya, Zimbabwe, Uganda, Malawi
Agroforestry	24	Senegal, Kenya, Uganda, Togo, Zimbabwe, Burkina Faso, Tanzania, Malawi
Mulching	9	Tanzania, South Africa, Burkina Faso, Malawi, Zimbabwe, Togo
Intercropping/companion planting	23	Tanzania, Kenya, Uganda, Zimbabwe, Togo, Malawi, Senegal, Burkina Faso
Cover crops	4	Senegal , Uganda, Sierra Leone, Malawi
Crop rotation	12	Kenya, South Africa, Togo, Malawi, Zimbabwe, Tanzania, Senegal, Burkina Faso
Open Pollinated/Indigenous Seed	5	Kenya, Zimbabwe, Uganda, Zambia
Livestock integration (e.g. Silvopasture)	11	South Africa, Kenya, Uganda, Zimbabwe, Togo, Tanzania, Burkina Faso
Contour cropping	2	South Africa, Tanzania
Bench terracing	1	Tanzania
Vetiver grass systems (border grass)	2	Tanzania, Kenya

Pesticidal plants	9	Malawi, Kenya, Zambia, Zimbabwe, Tanzania, Kenya, Burkina Faso, Sierra Leone
Water conservation (ridges, pits, rainwater harvesting, swales-on-contour)	21	Tanzania, Kenya, Zimbabwe, Uganda, Burkina Faso, Malawi

Projects that focused on soil and water conservation techniques, such as contour stone bunds, improved traditional planting pits (zai), and rock dams for gully rehabilitation led to improved soil fertility, raised groundwater levels, and increased cereal yields in participating areas. For example, a Soil and Water Conservation project in Moshi, Hai, and Rombo districts of Tanzania saw a doubling of maize yields (1.3 to 2.6 tons per hectare), as well as bean yields (0.7 to 1.2 tons per hectare). There was also an increase in milk yields from goats (0.5 to 2.5 liters per day) and cows (4 to 7 liters per day). The project was started in 1996, and by 2005 a total of 6,500 farmers from eight villages had applied conservation techniques on land spanning over 4,200 hectares. Practices implemented ranged from contour farming, crop rotation, ridges (fanya juu terraces), intercropping, mulching, agroforestry, and vetiver grass systems. In addition, the project involved developing irrigation canals and terraces. Zero-grazing was also promoted to protect the environment and improve livestock management. These combined efforts led to increased soil fertility, reduced erosion, and improved water infiltration, resulting in the observed increases in farm outputs (17).

Another Tanzanian project that focused on organic pineapple farming in Karagwe District, implemented agroforestry, organic manure, and soil fertility management techniques such as contour farming and mulching to improve soil quality (14). This led to reported reductions in erosion and increased soil moisture retention. Regarding crop yield, pineapple weights reportedly increased from 0.5 to 4 kg, with prices rising five-fold (TSh 40 to TSh 200). The project was started in 1997 with the training of 115 farmers, and by 2006 had expanded to train over 1,000 farmers across three districts. A total of 80% of trained farmers adopted mulching, 76% adopted mixed cropping, 66% applied manure, and 40% took up composting. There were also reported yield increases in other crops such as beans and bananas, which ultimately contributed to the reported reduction in food shortage periods from four to two months. The project was so successful that the business further expanded, with contracts signed with 300 farmers and 30 permanent employees as part of an international value chain for dried fruits. It was reported that by 2010, the company had an annual turnover of over US$60,000.

In 2006, a conservation farming project in Nkayi District of Zimbabwe implemented minimal tillage, mulching, and planting stations, to boost soil fertility and reduce erosion (5). The application of these practices, including community seed banks led to an improvement maize yields, with farmers reportedly achieving 4.3 tons per hectare compared to 0.4 tons per hectare from conventional fields. In addition, the adoption of use of organic fertilizers significantly reduced farmers' reliance on chemical fertilizers and improved household food security.

In Mashonaland East Province in Zimbabwe, a project aimed at promoting a shift to agroecological farming, focused on rebuilding soil fertility by promoting practices such as composting, mulching, and agroforestry (9). In addition, practices such as intercropping and crop rotation led to reported improvements soil structure and biodiversity, while also boosting crop yields and household incomes. As a result, involved farmers saw a 72% increase in yields and a 90% rise in income within the first 18 months. Within this time-frame, an increased in agrobiodiversity by 122% was also observed. The initial 591 participating farmers saw improvements in farm diversity, yields, and incomes. The project later expanded to include an additional 200 farmers and 3,562 members in the national organic membership body. The project's success led to the establishment of Zimbabwe's first 160 hectares of locally certified organic land, which earned a total of US$ 69,800 over a period of 30 months.

In Senegal, a long-running regeneration project was started in 1987, with the aim of increase food security, reduce farmer dependence on external inputs, and improving soil quality (56). The project implemented practices such as composting, cover crops, stone barriers, intercropping, agroforestry, (integrating leguminous plants), and crop rotations. In addition, livestock manure and green manure was used, all of which ultimately contributed to improved soil organic matter and reduced erosion. This was exemplified by a reported 4.5-fold increase in millet yields with compost (1270 kg per hectare) compared to unfertilized controls (230 kg per hectare). In addition, milk yields from goats and cows also increased, due to improved fodder availability. These yields consistently improved year after year following the projects commencement, resulting in increased farmer revenue. The integration of agroecological practices also led to improved household food security and higher incomes through organic farming.

In 2017, a project conducted by the Biodiversity and Biosafety Association of Kenya (BIBA Kenya) in Nakuru County in Kenya, focused on replenishing impoverished soils and improving the understanding of climate change impacts on food production systems among farmers. Practices implemented included agroforestry, composting, and minimal tillage, which improved microclimate and rejuvenated soil. Ultimately, over 3,000 nitrogen-fixing trees were planted. The use of green manuring reportedly improved soil organic matter by 65%, as well as enhanced water retention. This led to increased biodiversity, with over 10 bird species reportedly inhabiting the farm. This re-balance of the ecosystems also contributed to reduced pest pressures. It also resulted in boosted farm productivity, with each crop cycle having a minimum growth rate of 40%. The farm eventually became a model for sustainable practices, having a positive impact on over 250 smallholder farmers and their communities (20).

In 2015, a project conducted in Kisumu West Sub County of Kenya implemented practices such as ridging, agroforestry, and organic manure application to improve soil health and control water flow. The project resulted in an increase in maize yields from 4 to 13 bags per season due to enhanced soil fertility. Community-driven peer learning and knowledge sharing further facilitated the spread of these sustainable practices. There was an increase in adoption of soil and water conservation practices from 200 farmers to over 1,500 farmers across seven villages, thus benefiting close to 6,000 household members. Income levels also reportedly rose by an average of 30% among households adopting these practices (22).

The Soils, Food and Healthy Communities (SFHC) Project launched by Ekwendeni Hospital in Malawi was started in 2000, and aimed to introduce legume-based cropping systems to address low soil fertility and food insecurity (46). The project implemented the use of groundnut, pigeon pea, and Mucuna cover crops to improve soil fertility, which contributed to between 30 and 90 kg of nitrogen per hectare annually. As a result, crop biodiversity was improved, along with soil moisture retention, ultimately leading to improved maize yields. Improved food security and dietary diversity was also reported, with more frequent consumption of legumes by participating households. Over 3,700 farmers tested legume technologies between 2001 and 2005, after which participation grew to over 10,000 farmers by 2011. This led to the establishment of a community legume seed bank, alongside ongoing farmer training. The project also empowered women, as female participation increased from 29% to over 50%.

A project started in the 1980s in the Central Plateau of Burkina Faso applied practices such as contour stone bunds, zai pits (improved traditional planting pits), and rock dams for gully rehabilitation (36). These methods improved soil and water conservation, as well as soil fertility. This led to increased millet (from 293 kg per hectare to 600 kg per hectare) and sorghum (from 232 kg per hectare to 700 kg per hectare) yields, and raised the groundwater table by more than five meters in many villages. The average cereal yields in villages practicing soil and water conservation practices were higher compared to control villages (793 kg per hectare vs. 611 kg per hectare). The project also reforested degraded areas, which enhanced biodiversity and stabilized the ecosystem. In addition, rural poverty in villages practicing these methods was reportedly reduced by 50% between 1985 and 1996.

In 2018, the Bokashi Fertilizer Initiative project was conducted in Zambia, which highlighted the effectiveness of Bokashi fertilizer in increasing organic matter and moisture retention in soils (58). This project led to a significant boost in maize yields from 2.7 to 5.0 tons per hectare. This was attributed to the increased organic matter density in soils, as well as improved soil moisture retention capabilities, which enhanced drought resistance. Sustainability efforts involved training farmers and developing partnerships with local organizations to enhance the widespread use of Bokashi.

Community and Social Benefits

Several studies highlighted broader social impacts, ranging from improved community cohesion, enhanced cultural sensitivity, as well as health and education benefits for farming households. In Tanzania, a project initiated in 2019 focused on the relationships between agroecological practices and farmer well-being in the Kilombero District. The study employed a three-tiered modeling approach, utilizing surveys of 467 households across seven villages. The findings indicated that the adoption of agroecological practices, such as mulching, intercropping, and the use of organic residues, not only improved soil health but also had significant positive social impacts. These included enhanced community cohesion and greater social stability within the villages. In addition, the study found that women were particularly empowered by these practices, which improved food security and economic opportunities, enabling them to take on more active roles in household and community decision-making (15).

A project initiated in 2020 in the Kiambu County of Kenya explored how agroecological practices could inform the development of local policy. The study used semi-structured interviews and questionnaires with farmers, extension officers, NGOs, and county assembly members. The findings highlighted the social benefits of agroecological farming, including improved community cohesion through farmer networks and community-based organizations. These networks facilitated knowledge sharing and supported the spread of sustainable practices, which improved agricultural outcomes and strengthened social ties within the community. The project also promoted cultural sensitivity, as it incorporated local traditions and knowledge into the farming practices, which helped gain wider acceptance and participation among farmers (18).

In the Mazabekweni region of KwaZulu-Natal, South Africa, a participatory action research project involving eight female-headed households implemented agroecological techniques on abandoned garden plots, including non-inversion tillage, precision placement of fertilizers, and the use of animal manure. The methodologies used fostered mutual labor assistance and shared decision-making among the participating households. These practices led to reported social benefits, such as enhanced community cohesion and the formation of group savings mechanisms (stokvels) to finance future agricultural inputs and maintain infrastructure. The project's focus on knowledge building and farmer-to-farmer extension further strengthened the community's social fabric (44).

Environmental Sustainability

Some case studies indicated a focus on integrating soil health with broader environmental and policy frameworks. In Zimbabwe, a project led TSURO Trust in 2012, aimed to restore the ecology of the area, promote sustainable livestock grazing practices, and improve livelihoods (10). It established a district dialogue platform on climate change and developed a participatory district climate change and watershed management policy. This resulted in reported improvements in land quality, revival of previously lost plant species, as well as enhanced community cohesion .

Following Cyclone Idai in 2019, the "Reviving Resilience" project in the Chimanimani District of Zimbabwe, focused on recovering from the devastation through sustainable agricultural and water management practices (7). The project included the establishment of Agroecology Landscape (AEL) groups and the development of community-driven conservation policies, which led to improved soil moisture retention, enhanced biodiversity, and effective water management that reportedly reduced erosion.

A project conducted in Tanzania in 2013 by Sustainable Agriculture Tanzania (SAT) involved the development of integrated pest management, biodiversity, and soil fertility practices (11). It also highlighted the importance of community involvement in environmental management and included initiatives such as field visits, practical training, and the establishment of farmer-to-farmer training networks. This resulted in improved soil fertility, improved water management, and enhanced ecosystem health, demonstrating the integration of agroecological practices with broader environmental strategies.

Market Access and Economic Benefits

Improved infrastructure and market access were reported outcomes in some case studies, leading to increased farmer incomes and better living standards. In Togo, a project initiated by Young Volunteers for the Environment (YVE) in 2004, focused on restoring land through sustainable agroecological practices and improving the socioeconomic situation of local women (51). It provided equipment such as motorized pumps for market gardening and supported income-generating activities for over 200 women. This contributed to improved crop yields and quality, enhanced food security, and increased market access, enabling women to sell their produce more effectively. The project also received overwhelmingly positive feedback from participants, demonstrating the successful integration of soil health practices with market opportunities.

In Sierra Leone, the "Organic Cocoa Production" project, initiated by Kpeya Agricultural Enterprises (KAE) in collaboration with Twin Fair Trading Organization (TFTO) in 2005, aimed to increase the incomes and food security of small farmers through the export of organic and fair-trade tropical products (61). Growers were organized into fair trade cooperatives, provided technical training in organic agriculture and cooperative marketing strategies, and developed export market opportunities for certified organic cocoa. As a result, KAE's membership grew from 700 in 2005 to over 1,200 by 2010, and cocoa export sales increased significantly from six tons in 2006/2007 to 27.5 tons in 2008/2009. Farmers received higher prices for their cocoa, resulting in improved household incomes and living standards. Higher income for individual producers, with prices reaching $1.10 per kg compared to $0.63 per kg from local traders.

Conflict Resolution

In some cases, the process of addressing land and resource disputes as part of these initiatives led to improved community relationships. In Zimbabwe, TSURO Trust-led project made significant strides in resolving land and resource disputes within the Chimanimani District (10). With the establishment of the district dialogue platform and participatory district climate change and watershed management policy, structured discussions among community members were facilitated, leading to improved relationships and cooperation. The establishment of environmental action groups and the creation of community bye-laws for environmental conservation further contributed to reducing conflicts and fostering community cohesion. As a result, the project reportedly strengthened social bonds within the community by providing a framework for constructively resolving disputes.

The Agroecology Landscape (AEL) groups formed in the "Reviving Resilience" project in Chimanimani District, Zimababwe in 2019, demonstrated the importance of conflict resolution in rebuilding community resilience (7). The project included community-driven conservation policies that addressed disputes over land use and resource allocation. Community members were involved in mapping and visioning exercises, which helped to resolve existing conflicts and prevent future disputes by promoting transparency and collaborative decision-making.

Health and Nutrition Improvements

Some projects contributed to better health outcomes within the community, largely due to improved access to nutritious food. In Tanzania, a project conducted in the Singida Rural District in 2016 focused on a nutrition-sensitive agroecology intervention, which involved a cluster-randomized trial across 20 villages. The intervention was found to successfully improve children's dietary diversity, increasing the dietary diversity score by 0.57 food groups and raising the percentage of children achieving minimum dietary diversity by 9.9 percentage points. The project did not report significant improvements in child anthropometry (e.g., stunting or wasting), as these are long-term indicators that require longitudinal monitoring. However, the intervention reportedly reduced household food insecurity alongside the promotion of sustainable agricultural practices (12).

In South Africa, a project conducted in 2011 in the Mazabekweni region of KwaZulu-Natal, employed the World Food Programme's Food Consumption Score (FCS) method to assess dietary diversity. As a consequence of the introduction of agroecological practices, households reportedly experienced improved dietary diversity, with homegrown food contributing significantly to their food security. The project also reported positive health outcomes and reduced food costs for the participating households (44).

In Malawi, the Never Ending Food project, initiated in 1997, focused on promoting permaculture principles through community-based demonstration sites and training programs (48). The project aimed to address malnutrition and food insecurity by encouraging the use of local, highly nutritious food plants. This contributed to enhanced nutritional diversity via the introduction of new crops such as bananas, yams, kale, and green peppers. The focus on permaculture and the utilization of local food resources resulted in improved diet diversity and overall health outcomes for the community, alongside improvements in soil health and farm biodiversity.

Challenges

Farmers faced several challenges in adopting agroecological practices across the target countries. Some of the most common included labor shortages, financial constraints, resource allocation issues, climatic variability (such as drought), and social barriers such as gender inequality. Collectively, these challenges affected the ability of farmers to adopt and sustain practices on a wider scale.

In Tanzania, a project in the Makete District highlighted labor shortages as a significant barrier. The implementation of soil and water conservation practices, such as bench terracing and intercropping, required substantial labor investment, which many smallholder farmers were unable to afford (16). This was particularly challenging in areas with high population density and limited available workforce. Farmers also struggled to secure the necessary funding to expand the reach of these practices. Similarly in Uganda, where an experimental agroecological farm was launched in Mityana Municipality in 2019, farmers faced difficulties in managing the initial labor and time required to establish productive systems (35). Although the 365-day green cover method reportedly improved soil fertility and reduces pest pressures, farmers had to invest significant effort before reaping the benefits, which was shown to deter adoption.

Also, in Senegal, a project initiated by the Union of Tattaguine Communities in 2011 to combat land degradation and soil salinization faced challenges due to the labor-intensive nature of soil conservation methods, such as the construction of anti-salt dykes and reforestation with salt-tolerant species (55). These practices, while effective in restoring land productivity, required significant community involvement and resources, which were often in short supply. Similarly, in Burkina Faso, where soil and water conservation (SWC) practices have been promoted since the early 1980s, farmers faced difficulties in maintaining the labor-intensive nature of techniques such as contour stone bunds, zai pits, and rock dams (36). These practices required substantial physical effort and resources, which many smallholder farmers struggled to afford. Consistent technical support was also often lacking, which limited the long-term sustainability of these interventions.

In Tanzania's Kilimanjaro region, where soil and water conservation efforts began in 1996, farmers have found contour farming and fanya juu (contour ridges) practices to be effective in reducing erosion and improving soil fertility (17). However, the initial costs and labor required to build terraces and trenches were high, which discouraged many farmers from adopting these practices. The lack of government or NGO support to subsidize these investments at the time further exacerbated the problem. In Burkina Faso, where organic cotton production has been promoted since 1998 by Helvetas, farmers faced labor challenges despite seeing long-term economic benefits (39). While organic farming reduced dependency on chemical inputs, the labor required for manual weeding, composting, and maintaining organic standards was higher compared to conventional methods. This made it difficult for farmers to transition to organic cotton production on a large scale. In the "Regenerative Agriculture" initiative, started in 1987 in Senegal's Groundnut Basin, farmers encountered challenges ranging from insufficient labor for compost production to inconsistent access to organic inputs.

In Kenya, a project in Kiambu County highlighted the financial constraints faced by smallholder farmers. Agroecological practices including organic manuring and crop rotation required initial investments that many farmers could not afford (18). Similarly, in Zimbabwe's Matebeleland North region, a conservation farming (CF) initiative started in 2006 faced challenges related to the cost and availability of organic fertilizers and mulching materials (5). Although essential, their limited availability meant that many farmers were unable to effectively implement CF practices. Moreover, community seed banks, which are critical for ensuring access to open-pollinated variety (OPV) seeds, faced challenges related to storage and distribution, particularly in remote areas.

In Senegal, a case study focused on land regeneration and combating soil salinization in the Fatick region, initiated in 2011, faced challenges with securing long-term investment to sustain the implemented practices (56). These challenges were exacerbated by the financial costs associated with building infrastructure and maintaining the necessary labor for sustainable soil management.

In Tanzania, the "Growing Organic Pineapples" project highlighted challenges related to certification processes (14). Farmers faced difficulties in meeting organic certification standards, which limited their access to premium markets for their organic produce. The costs of maintaining organic practices, coupled with the requirements for inspections and certifications, posed significant financial and logistical barriers.

In Kenya, a case study involving agroforestry and intercropping in the Vihiga and Kakamega counties revealed that farmers initially resisted adopting these methods due to the time and patience required before seeing tangible benefits (24). The long-term nature of agroecological practices, which often require years before they begin showing improvements in soil health and yields, made it difficult to convince farmers to switch from conventional methods. The high initial costs associated with setting up agroforestry systems were also seen as risky investments by many farmers.

In South Africa, a project focusing on implementing agroecological cropping systems in rural KwaZulu-Natal households, reported that prolonged droughts posed a significant challenge to adoption. Despite the clear benefits, erratic rainfall patterns led to crop failures, making farmers hesitant to adopt practices that depend on predictable water availability. Moreover, the lack of state infrastructure support for irrigation systems exacerbated the challenge (44).

In Uganda's Karamoja region, where agroecological methods were introduced to enhance soil fertility and improve water management, farmers faced significant challenges related to water scarcity (32). The implementation of water harvesting techniques such as retention ditches and contour planting was often hindered by insufficient technical knowledge and funding. This affected the farmers' ability to fully utilize these practices to combat the arid conditions prevalent in the region.

In Kenya, where the project at Rehema Farm that began in 2017, farmers encountered challenges related to inadequate research and funding in arid and semi-arid lands (ASALs) (27). The focus on more fertile regions left these areas with limited resources and technical support, thus hindering the adoption of agroecological practices. As a result, farmers often faced ongoing difficulties in improving soil health and crop productivity.

In Malawi, the "Never Ending Food" project initiated in 1997 focused on promoting permaculture to reduce malnutrition and food insecurity (48). However, challenges arose due to the stigma associated with traditional foods, which were sometimes seen as "poor people's food." This cultural perception hindered widespread adoption of permaculture methods that promote the use of local food resources. Government policies also tended to prioritize maize production, limiting the promotion of diversified, nutritious crops that were central to permaculture.

In Malawi, the "Legume Diversification" project started in 2000, faced challenges with scaling up legume intercropping and crop rotation practices (46). Despite experiencing success with improved yields, farmers often struggled with limited access to legume seeds and the technical knowledge needed to effectively implement these systems.

In South Africa, a project focused on large-scale dryland sugarcane farming in the KwaZulu-Natal Midlands, highlighted the difficulty farmers faced due to a lack information on practical soil health monitoring tools. The integration of conservation agriculture principles into conventional sugarcane farming has been slow due to the high costs of transitioning and the need for continuous training (43).

In Togo, a long-standing project that began in 2004, demonstrated that farmers faced significant challenges related to the availability of equipment, such as pumps for irrigation and tools for biofertilizer production (51). Without the necessary resources to produce biofertilizers at scale, many smallholder farmers struggled to fully adopt these sustainable practices.

Key Informant Interviews

The thematic analysis presents findings from four key informant interviews conducted with experts in agroecological practices from the target countries (Malawi, Tanzania, Uganda, South Africa). The interviews explored various aspects of agroecological farming, focusing on practices that improve soil health, challenges faced in implementing these practices, and their impact on community livelihoods. The analysis revealed several key themes, including the use of organic inputs, agroforestry techniques, and traditional farming methods to enhance soil fertility and sustainability. It also highlighted the challenges of limited extension support and farmer perceptions, as well as potential solutions through training programs and policy changes.

The analysis also examined the effects of these practices on food security, nutrition, and local economies. The insights gathered from these interviews provide an overview of the current state of agroecological practices in African farming communities and their potential for improving agricultural sustainability and rural livelihoods.

Agroecological practices

Organic manure

Agroecological practices center on using organic inputs and other traditional farming methods to improve soil health and sustainability. Organic manure, including various forms such as bokashi and farmyard manure, enhances soil fertility by adding essential nutrients, microbes, and enzymes. These inputs nourish the soil and promotes beneficial microorganisms that are critical for soil regeneration. All interview respondents indicated that farmers utilized various types of organic inputs to maintain soil health and productivity, while in turn reducing their dependence on synthetic inputs.

A1(Uganda)
" …so the using of green manure method, but also using or recycling of organic matter by mulching them. So those have been really very, very important.

…you find animal manure has a lot of nitrogen, but also, most important, it has different types of microorganisms. It has different types of enzymes. It has different types of hormones, which come out from the gut of the animal. And this one, once you use it in your fertilizer, your fertilizer has different minerals, it has different chemicals. For example, as I said, it has antibodies, it has antioxidants, it has microbes, it has enzymes, and that comes from the animal side. So you can never be an agrecological person without animals."

A2 (Malawi)
"So we promote the use of organic manure. Farmers use different types of organic manure, like bokashi, farmyard manure. To some extent, some use liquid manure".

A3 (South Africa)
"Introducing bio inputs. …and then those bio inputs were a whole range of things taught from Bokashi to various fermented cow dung recipes to dry cow dung recipes. To seed coating to some fermented pesticide applications, all using organic ingredients. So we've tried to implement all of them."

A4 (Tanzania)
"some other activities that have been specifically being done…the use of naturally occurring microbes in the soil to regenerate it, but also to create some bio fertilising products and services."

Agroforestry

Agroforestry integrates trees, particularly leguminous varieties, into farming systems to improve soil fertility and prevent erosion. Respondents indicated that farmers planted a diverse species of trees alongside crops such as coffee and bananas, benefiting from their nitrogen-fixing abilities and soil conservation properties. They also reported that local knowledge played a key role in selecting tree species, and efforts are made to protect young trees through water conservation practices and fencing.

A1 (Uganda)
"We currently brought somebody to help us actually map out the different types of trees. We are looking at trees only. We have a 16- acre piece of land, and (in) the 16 acre piece of land we identified over 60 different types of trees, different types of species of trees. And that makes our place to be really something different. So you find diversity is another very important technology which is actually important. For example, we have different types of trees in my area here, the [ficus] trees. The ficus trees are good for to be inter planted together with either coffee or banana. And this has become really local knowledge, not knowledge which has come (from) outside."

A2 (Malawi)
"So *the most impactful practice has been the integration of leguminous trees, those that improve soil fertility. I think this is mainly because the use of indigenous trees (is) as old as agriculture itself in communities that we are working with. So farmers at least have local knowledge about the trees that they integrate, and they know which trees improve soil fertility, and conserve the soil. So by promoting conservation of those trees on (the) farm, promoting things like regeneration, farmer-managed tree regeneration, they improve the failure of the farmers.*

We also have tried to encourage farmers to tender these young trees, for example, they can construct during poor rainfall season, they can construct water bases to harvest the little moisture. They can cover those bases with glasses, just to conserve moisture so that at least the young trees can grow into into mature trees."

A4 (Tanzania)
"There has been efforts in landscape wide issue to study the roles of farming practices and how they impact the erosion, and some sustainable ways of regenerating the soil, such as the use of leguminous plants. That's actually leading to soil enrichment, soil fertility enrichment, but also acting as a way to manage long term erosion of the soil."

Mulching

Mulching is a widely adopted practice that helps conserve soil moisture, maintain soil temperature, and add organic matter to the soil. Respondents indicated that farmers used crop residues, such as maize stubble, to cover the soil, which aided in water retention and keeps soil microbes alive. This technique serves a dual purpose: it improves soil health and acts as a water conservation strategy..Mulching was recognized as a key component of climate resilience and was commonly practiced improve long-term soil fertility.

A2 (Malawi)
"And we also have tried mulching, once the farmers have based their crops, they can just mulch. For example, for instance, maize, because we are a maize producing country, that's our staple. So I'll use this example, then I just cover their soils with the maize. That is also not a difficult task, because by doing that, the materials can at least add organic matter to the soil."

A3 (South Africa)
"And also on that is a very important emphasis on mulching. So mulching helps the soil health because it helps keep the soil moist and keeps the microbes alive. But it's also a water conservation strategy. So that's why I say a lot of these things double up and they're both water conservation and soil health."

A4 (Tanzania)
"So we are doing a lot of awareness about it (climate change), but also we're seeing resilience coming from the farmers practices. The issues of mulching, water retention. Studying the landscapes, these are being done (by) the farms on the farmers fields and they're helpful. Maybe not in a very short time, but also but they are

there and they have a promising future, so to say."

Local/Indigenous seeds

The use of locally adapted seeds can play a key role in ensuring resilience to environmental stresses, such as drought and poor soil conditions. Respondents indicated that indigenous seeds such as traditional maize varieties offered greater adaptability and consistent yields even in unfavorable conditions. Seed diversity was essential for maintaining soil health, as different crops, particularly legumes, help improve nitrogen levels and soil fertility. Reviving traditional seed varieties had also become a key strategy for ensuring food security and soil regeneration.

A1 (Uganda)
"we are seeing that using locally adapted seeds (is) very, very important, because when you use the locally adapted seeds, but also local seeds, you find that these seeds can withstand the stress within our localities. For example, for us here, we have started multi,plying, collecting and multiplying indigenous maize seed, but not also other different types of seeds. So, but we are looking at indigenous seed, and we find that by the use of the indigenous seed, we actually have food throughout the year, and not the food which we're eating for the sake of eating, but the food which our people are used to.

…local seeds, even if the weather is not good, they will survive. You don't get a total failure."

A3 (South Africa)
"...and we've introduced militant sorghum. And reintroduced it back where it's been lost.

seed is quite a important foundation of the agricultural work we do. So it's reviving traditional varieties of crops that people have and are losing, and focusing on seed exchanges, etc. And that's also quite an important aspect of soil health, because if you don't have the right legumes or the resilient varieties and farmer varieties that can grow in all these different conditions, you can't have the cover crops and the legumes to improve your soil, etc, etc. So seed diversity is also an important part of it."

Intercropping

Intercropping involves planting diverse crops together to reduce pest pressures and improve soil health. Farmers can create a self-regulating ecosystem that minimizes pest infestations and reduces the need for synthetic pesticides, simply by growing multiple crops, such as legumes alongside grains. Intercropping also contributes to soil fertility, with nitrogen-fixing plants like legumes enriching the soil. Respondents indicated that this practice enhanced both biodiversity and sustainability, promoting natural pest control and soil health.

A1 (Uganda)
"Another technology of agroecological technology is diversity, diversity. And I think this has really performed magic. If you have different types of crops growing together, from our experience, the first thing is the pest and diseases incidence is highly reduced. Because you find these different pests, different plants, different crops, they are they have different needs. But also pests which need them are different. And you find, because of these mixtures and diversity, we get pests confused, and they don't attack our crops. And you find even sometimes, we don't need to use bio-protectors, because we have developed a system, self regulating system, and that self regulating system is brought about by the diversity"

A3 (South Africa)
"…in all the planting we encourage intercropping, Like multiple crops. So again, that's also a soil improvement strategy, because the legumes help to put nitrogen into the soil. We also have the soil covered by those intercropping techniques. So you have creeping plants like the different [kookabets] and the legumes providing a living mulch. So you don't have to try and cut mulch because most areas don't have very much extra organic material available.
And all of that then helps to keep moisture in and also keeps fertility in the soil."

Challenges

Lack of extension staff support

Respondents identified the he lack of support from government extension services as a major challenge to promoting agroecological practices. Based on their training, extension workers often focused on promoting conventional farming methods, such as the use of synthetic fertilizers and pesticides. Government subsidies for these inputs also reduced the motivation for farmers to adopt sustainable practices such as organic manure production, which led to a slow uptake of agroecological methods.

A1 (Uganda)
"But then the technical people don't have the knowledge about agroecology. They have been trained in conventional way of farming, and therefore, when they are advising the farmers, even when they come to the agroecological farmers, will find they cannot advise them because they don't have the knowledge. So we still have that gap, a very big gap, whereby many of our extension workers do not have the knowledge about agroecology, and therefore you find people who can advise rightly. They are quite, quite, quite few. So still have that challenge."

A2 (Malawi)
"Another challenge could be limited support in terms of extension services. You know, farmers depend so much on the government extension staff. Yes, NGO staff are there, but government extension staff are always in the communities, and most of these government extension staff, they do not promote sustainable land management practices like the use of organic manual practices. What really they promote are practices that are leaning towards conventional agriculture, because they know that government will support these farmers with subsidies, so they don't put much effort into supporting the farmers to make like organic manure. So that is also another challenge that we have seen."

A3 (South Africa)
"So like you might get someone who comes and like wants to do this climate smart training. But it's not in that comprehensive, holistic way that agroecological farmers approach production."

Labor shortages

Labor intensity was also identified by respondents as a significant barrier to adopting agroecological practices, particularly for practices such as bokashi production and application, which required considerable time and effort. Respondents expressed concerns about the availability of labor to implement these practices effectively and the potential increase in workload for farmers already facing time constraints, particularly women. Hence, the labor-intensive nature of certain agroecological practices may deter them from fully embracing them, despite recognizing the long-term benefits.

A2 (Malawi)
"On sustainable land management, most of them, they require a lot of labor, for example, for farmers to make organic manure, to apply, let's say, to a hectare, there is a lot of labor that is involved, and especially for female smallholder farmers, that becomes a challenge. Even gathering the materials themselves is also a challenge, because they have to gather, let's say, plant biomass, so that they can compost make a bed. So the whole process involves a lot of labor, and not easy for for women."

A3 (South Africa)
"Our farmers have found bokashi she really to be a great amendment and they want it, but they struggle with. The access to the ingredients to make it and also the labor 'cause it's quite labor intensive so. It hasn't taken off in that many places for that reason.

But the fertility beds take a bit of work, so he encourages the farmers to work in a group in their area and create some. This is called "ilima" like a work party that rotates where you support each other and you you go to one person's house this week and another person's the next week and you help each other with the labor. And then just the labor of it, especially with the ones like bukashi that need a lot of days and turning and it's quite physical."

Farmer perception

Respondents highlighted that many farmers remained skeptical about the effectiveness of organic practices, perceiving them as less productive compared to conventional inputs. The availability of government-subsidized chemical inputs further discourages the adoption of sustainable land management practices. As a result, there was a lack of incentive for farmers to switch to organic methods that may require more effort and resources initially. This perpetuated the cycle of dependence on chemical inputs that contributes to environmental degradation.

A2 (Malawi)
"...the mindset of the farmers is also a challenge, because the farmers that we are working with have mostly depend(ed) on subsidies from from the government. So they wait for government to come in and maybe reduce the cost of organic fertilizers so that they can buy. Some of them, because of that mindset, they don't really believe that the use of organic manure can work some of them. They think that it gives slow results as compared to inorganic fertilizers. So really, government programs like subsidies affect the use and adoption of sustainable land management practices. For instance, the use and the making and use of organic manure."

A3 (South Africa)
"The practices don't spread enough… I think the farmers also complain, they try and introduce some of them to neighbours, but they don't always get adopted. And some of that is because some farmers get subsidized inputs through the agricultural extension, and agricultural extension is very much focused on industrial model and they say that like the old ways are bad and backward etc."

A4 (Tanzania)
"One very apparent challenge is competition that we have, the competitors from the synthetic chemicals, pesticides, synthetic fertilisers. But also we have challenges about their awareness. So we know what works effectively is they think tactic is the one that is derived from the industry, so in the shops as compared to sustainable options that will be maybe slowly showing impacts that will require patience to wait for a year or so or a season or something like that. These are challenges."

Solutions

Training farmers

Respondents highlighted the importance of training programs, with one respondent making reference to the "train-the-trainer" model run by AFSA, which has been used to disseminate knowledge of agroecological practices across communities. Lead farmers were taught sustainable practices and tasked with training others, creating a multiplier effect. Additionally, the respondent suggested that agroecology should be integrated into education systems, from primary schools to universities, to build long-term capacity.

A1 (Uganda)
"For example, under the Healthy Soil Healthy Food Initiative, which has been funded by, which was supported by AFSA, we have had a system of training-of-trainers. So we selected trainers from different parts of the country, we gave them the training, and we tasked them to go and train other farmers, and we gave them numbers. And we say each farmer who is trained must also train other farmers. For example, these original duties, each one was asked to train 10 farmers and those trained farmers, each one was supposed to train five farmers. And because of that, you actually find within the community, anybody who is trained for us we call them trainers. So once we train you, or once the trainer trains you, you become a trainer, and you are supposed to train other people. And I actually have seen this one being a very effective way of trying to take the knowledge to different communities.

what I would do, recommend, is to see that there is an effort towards putting agroecology and principle training right away from the young. Those children, school children from the primary school, secondary school. And it was because for now, we have a few universities which have started training in a bachelor's level, master's level and PhD, but before that, there is no agroecology apart from us. Here, we started already a diploma course in agroecology, but it hasn't been approved by the National Council of Higher Education. But we already put our curriculum, and they are reviewing it to see that we can also have a diploma course in *agroecology. But I think, I recommend that it should be streamlined in all academic institutions, starting from the lowest to the highest."*

A2 (Malawi)
"We have tried to mitigate that by working with what we call Lead Farmer Models, where we train a smallholder farmer and this smallholder farmer will recruit what we call 'follower farmers' within his maybe, say, a village, so that we upskill sustainable land management practice, so that not only is this lead farmer practicing, but also these other follower farmers are learning from this lead farmer and practicing the sustainable agriculture practices so that it is done at scale."

Government support

Respondents also called for governments to shift focus from subsidizing chemical inputs to supporting sustainable land management policies and practices. This would include investing in agroecological practices, promoting conservation agriculture, and providing training and resources to allow for easier adoption. This is important as supporting sustainable land management practices can also lead to increased resilience to climate change and contribute to overall food security.

A2 (Malawi)
"Most of the support goes towards the subsidy programs which promote inorganic fertilizer. So if government can fund/support land resources department and change these policies, put more resources instead of supporting a lot of these subsidies. If they can put resources to sustainable and management practices, I think these will be long term plans that will be sustainable, rather than the use of inorganic fertilizers, because they are not sustainable. So government really need to realign itself with agricultural practices by supporting its own department, which is called the land resources department, and also at policy level, government extension staff should also support sustainable land management practices."

A3 (South Africa)
"The policy is very geared towards industrial agriculture and commercial farming.
And the climate response, for example, is focused on climate smart agriculture. So that sounds like a good thing. But actually, the way it's implemented in South Africa is more sort of introducing low tillage together with herbicides. So it's it's been round-up ready or herbicide-resistant GMO crops with herbicides etc".

A4 (Tanzania)
"What we've tried to do, and maybe I'll just say it in my own perspective, is having a very nice engagement with the stakeholders so that we together identify the problem.We together understand the problem quite clearly and we see how it impacts each party from the word go. This helps to actually design interventions. This also helps in the way we interpret the results. So now instead of saying 'this didn't work', this is on. We are seeing what had actually changed.

There has been an organic agroecological strategy that has been enacted by the government. So it's a very huge step that a government, of course through private actors and other stakeholders have managed to really step up. And we try to facilitate the government's efforts to create a law that facilitates agriculture activities in there, and practices in Tanzania. So that helps in a policy-wise. Although not so effective/active to an extent that we would really desire, but at least in comparison with the past experiences we're making headways."

Improving community livelihoods

Food and nutrition security

Respondents highlighted that agroecological practices have significantly improved food security and nutrition in farming communities. Farmers report higher productivity and year-round food availability due to healthier soils. These practices have also proven resilient during periods of climate stress, such as droughts, and during the COVID-19 pandemic, when local food production became critical for food access.

A1 (Uganda)

"But also, when you look at the farms of these people who are farming ecologically, I think their productivity is very high because they produce throughout the year, because the soil has really changed drastically. So productivity is high. So I think there is they have food. They have more food throughout the year, they are saving money."

"But also what I am observing agroecological communities, they mind about what they eat. They don't just eat anything they know, because they have been become very aware that what they eat is actually affecting their lives. If you eat well, your life will be well. If you don't eat well, your life will not be well. So they mind about what they are eating. And I think that is something very important for me as I look at it, that's what I think incomes because they serve. They have food throughout the year. But also they know what they eat. They don't just eat everything."

A2 (Malawi)
"So by improving soil health, we have impacted our smallholder farmers in terms of improving their livelihoods, for instance, food and nutrition security, because when they have got heavy soil, it will be able to support a healthy crop, and the production then grows, and farmers are able to harvest a good crop which will contribute to food security."

"And not only that, because most of our diets are plant based. So by improving soil fertility, in a way, we also address hidden hunger. Because most of our crops, they get nutrients from the soil. And if these nutrients are lacking, it means will not access these nutrients. For example, simple trace, elements like zinc, you know, crops have to get them from the soil. Things like iron. And what if they are not there, then we will be in problem."

A3 (South Africa)
"And the benefits have been that they have much improved household nutrition, so that was very evident. It's been very evident when they have been climate issues or on the back of droughts when a lot of smallholders just didn't do anything because nothing would grow. Also, during COVID, we found that a lot of the the rural households swelled with family members that came from back from cities, like from the jobs in the cities. And so they had very big households during those that time and on the whole they managed very well because they had enough produce to feed everyone and it was diverse and they didn't have to rely on going to the shops, whereas other people were struggling because they weren't allowed to move around or they couldn't get transport or transport was expensive. So they were much more resilient."

Savings/Boosting income

Respondents indicated that agroecological practices also reduced input costs, which further supported household savings and income. As farmers experienced improved soil fertility and crop yields as a result it allowed them to produce higher quality crops for sale. Some farmers were also able to produce and in some cases sell their own organic inputs as the demand steadily increased, which also led to increased savings and earnings.

A1 (Uganda)
"…and also the cost. Because what we actually encouraging is that farmers/communities are able to make their inputs by themselves, not buying. And therefore you see that is the saving. Instead of going out to buy farm inputs, they make them that has been really saving is very, very important."

A2 (Malawi)
"But also, it contributes to incomes among the smallholder farmers. For instance, when farmers have a surplus, they can sell that surplus, they have access to money. And I've seen that some farmers now are making organic manure for sale. So it's also a business that is moving in the communities, this is because of inorganic fertilizers have become very expensive. And for government, it has also become unsustainable, because they have to pump in a lot of money. So the demand for organic fertilizers is increasing. So those farmers, some of them, make organic manure and sell so it's also, in a way, indirectly, contributing to their incomes."

A3 (South Africa)
"And many farmers also have extra that they can sell. So, some farmers focus on selling seed. Because there is interest in crops that aren't commercially available and some just focus on selling their surplus.

We've got one Gogo (grandmother) she's done her own trials with the different bio-inputs and she can really demonstrate the difference it's made. And so, she's willing to invest cash to pay young young guys to help her with some of the labor, because of the benefit."

Agroecological Markets

Lack of standards/certification

Respondents highlighted that a lack of formal standards and certification for agroecological products limits their marketability. While some regions use the participatory guarantee system (PGS), where farmers self-certify their products, this system remains underdeveloped and lacks consumer awareness. Penetrating larger markets, such as supermarkets was reported to be difficult due to the lack of certification, which undermined the visibility and trust in agroecological products.

A1 (Uganda)
"But if you ask, what are agroecological products? People cannot say it should look like this, because they don't have any standards. And that has been a big debate here, for example, you come to marketing, you see, okay, what? What will show that it doesn't have a standard, it doesn't have labels. That's why we are saying we are talking about organic standards. But these organic standards, we are using what we call participatory guarantee system, whereby, yeah, we have a few groups in Uganda which have been certified using the participatory guarantee system. That's whereby the farmers themselves make their own standards, make their own procedures, and they declare themselves as agroecological. So we have in Uganda a few isolated markets, in small markets, whereby people go and are exclusively agroecological and therefore people go there to buy agroecological products. But still, because there's no distinction, there are few people who know those places and who can go to those places. So that's a big challenge, which must be addressed."

A2 (Malawi)
"And also another challenge is to penetrate, you know, other other big markets, like a supermarket, because of regulations by government bureaus we are promoting. We are supporting the farmers with some value addition. They are producing peanut butter. As I was saying, most of the products are not certified. We don't have any certification, so its mainly based on trust for the AE products. So maybe some consumers would want products that are certified so that becomes a challenge."

A3 (South Africa)
"Many years ago we did try a bit around trying to work around participatory guarantee systems and had someone try and work with farmers to develop a sort of like their own idea of a brand and are using the participatory guarantee system principles. But it didn't take off that well at the time and I don't know if it was just in terms of volumes…
And marketing is quite tricky I think because you do have to have enough volume, and you've got to meet a whole lot of standards and criteria."

Indicators of Soil Health

Respondents indicated that farmers assess soil health using simple yet effective indicators such as the color and texture of the soil, pest infestations, and the presence of macro-organisms such as earthworms. Darker, crumbly soil with a high presence of macro-organisms was a clear sign of improved soil health. Healthy soils support more resilient crops, which are less susceptible to pests and diseases. These indicators helped farmers monitor the impact of agroecological practices on soil quality over time.

Soil Quality
A1 (Uganda)
"I will give a very simple example, when you go to a garden, the first think is, when you look at the weight of the plant, you have to uproot it, one plant as a test. And if that plant comes with a lump of soil on its roots, then it indicates that the soil fertility is good, because the soils are in crumbs, they can stick. So when you pull

it, it comes not as a plant where the roots are just inside, but it comes with the lump. So you find the soil crumbs are attached to the roots. So that is a very good indicator that the soil fertility has increased."

A2 (Malawi)
"We also encourage the farmers to be checking the color of the soil. It can be an issue of the palliative material, but they should also be able to notice the soil changes once they are applying organic manure, because we told them that it changes. Maybe it was lighter, but then it becomes black.
So that's what I'm saying. So soil color is one of the easier indicators that we tell the farmers to be to be checking that."

A3 (South Africa)
"Farmers also very much look at the health of the crops and the size, so they'll compare like how's mine doing compared to the neighbours in terms of if it's maize, the height of the maize, the size of the cobs, the health, do they get attacked by pests…"

Macro-organisms

A1 (Uganda)
"Another very important one is the pest occurrences. For example, when you see a plant that is fully infested with pests, that's an indicator that the soil is not actually healthy. Because a healthy soil but give a healthy plant. And a healthy plant must be able to resist and protect itself from heavy pest infestation, as especially as you say we are agroecological we are encouraging people to grow local varieties and locally-adapted varieties".

A2 (Malawi)
"We mainly encourage the farmers to check what we call the macro-organisms from the soil. So we say that once your soil health is improving, you're going to have a lot of macro, these small animals, earthworms, what, what. So once you see that, it means your soil is improving. So it's one of the major indicators that farmers really do."

Discussion

The results of this meta-analysis offers an evaluation of agroecological practices across the 11 target countries, highlighting their impact on soil health, agricultural productivity, human well-being, and community resilience. In the context of the Healthy Soils, Healthy Foods (HSHF) project, the findings underscore the potential of agroecological approaches to transform farming systems in Africa, particularly for smallholder farmers who are most vulnerable to soil degradation and climate change. These findings align with a growing body of literature that highlights the importance of organic inputs, biodiversity, and sustainable land management in promoting long-term soil health. It also spotlights the significant challenges that remain in terms of government support, labor shortages, and market access.

The study demonstrated that agroecological practices such as the use of organic manure, agroforestry, and intercropping can significantly improve soil health indicators, including organic matter content, nutrient availability, and soil structure. The use of organic inputs such as green manure, animal manure and bokashi was found to improve soil organic matter and nutrient cycling in several case studies across the target countries, confirming previous research that underscores the benefits of organic fertilization for long-term soil health. These findings align with existing literature that highlights the role of organic inputs and diversified cropping systems in enhancing soil fertility and microbial activity. Both play a pivotal role in enhancing soil fertility and microbial activity by contributing to improved soil structure, and moisture retention. The addition of organic materials, such as compost, manure, and crop residues, promotes the accumulation of organic carbon, which is crucial for soil fertility and resilience (Kopittke et al., 2024). In addition, they provide essential nutrients that are gradually released into the soil, fostering a more balanced and sustainable nutrient profile, as compared to synthetic fertilizers. Diversified cropping systems, including crop rotations and intercropping, encourage a rich diversity of plant species that support a variety of microbial communities. These microbes contribute to breaking down organic matter and facilitating nutrient uptake, ultimately leading to healthier soils. Furthermore, diversified systems help reduce pest and disease pressures, decreasing the need for chemical inputs, and promoting a self-sustaining ecosystem where both soil health and crop productivity are optimized (Souissi et al., 2024).

The inclusion of agroforestry in many of the case studies further supports the importance of integrating trees into farming systems to enhance soil quality. Several case study findings demonstrated the effectiveness of agroforestry in increasing crop yields and restoring degraded lands. Agroforestry contributes to soil enrichment by fixing nitrogen, reducing erosion, and improving water retention (Amede et al. 2023). Thus, it plays a critical role in sustaining soil health in regions affected by monocropping and deforestation, where land degradation is a significant concern. Agroforestry systems involves the integration of trees with crops and livestock to enhance soil structure, prevent erosion, and increase organic matter, all of which contribute to improved soil fertility. The deep root systems of trees in agroforestry stabilize the soil and help with nutrient cycling by accessing nutrients from deeper soil layers, which are then made available to crops. This system also promotes biodiversity, fostering beneficial microorganisms that further enhance soil health (Amundson et al. 2015).

The use of mulching as a soil health intervention was particularly noteworthy. Qualitative results highlighted that mulching can improve soil moisture retention and enhance soil microbial activity. This is corroborated by findings from Burkina Faso, where mulching was found to increase grain yields by up to 55%, demonstrating its potential to improve food security in regions prone to drought (FAO, 2023). Mulching helps retain soil moisture, reduces evaporation, and moderates soil temperature, creating a more stable environment for plant growth. These benefits are critical in drought-prone areas, where water scarcity is a constant challenge . The increased yields observed in several case studies demonstrates its potential to significantly contribute to food security, offering a sustainable solution to improve agricultural outputs under challenging environmental conditions. These outcomes further underscore the importance of organic matter management in sustainable farming systems, as organic inputs help maintain soil fertility without the need for synthetic fertilizers.

One of the key findings was the direct link between improved soil health and increased agricultural productivity, as measured by increased farm outputs. Several case studies showed that agroecological practices led to significant increases in crop and livestock yields. These findings are consistent with research that highlighted the the integration of techniques such as intercropping, agroforestry, and organic inputs has enhanced soil fertility, improved water retention, and promoted biodiversity, all of which contribute to increased productivity. Research indicates that intercropping enhances plant resilience, optimizes land use, and increases yields by improving nutrient cycling and reducing pest pressures (Zenda and Rudolph, 2024). In addition, intercropping cereals with nitrogen-fixing legumes improves soil nutrient availability, leading to higher grain output. Livestock productivity has also increased through integrated crop-livestock systems, where organic waste from animals enhances soil quality, contributing to a cycle of improved crop and animal health (Akanmu et al. 2023). Also, agroforestry systems in addition to boosting crop yields by improving soil health and providing crops with shade and wind protection; they also provide livestock with additional sources of fodder, which in turn boosts livestock yields (Zenda and Rudolph, 2024).

Several case studies demonstrated the value of diverse cropping systems in reducing pest pressure and improving crop resilience. This highlighted the wider environmental benefits of agroecological practices, particularly in terms of biodiversity and ecosystem services. This is consistent with broader studies showing that agroecological practices help create self-regulating ecosystems, where natural pest predators and pollinators thrive, reducing the need for chemical inputs. Agricultural systems that incorporate biodiversity, such as crop diversification and the integration of livestock, are more resilient to climate change and better able to maintain long-term productivity. Biodiverse systems have been shown to be more adaptable to environmental stressors, including droughts, floods, and pest outbreaks, as they rely on a broader range of species to provide essential ecosystem functions (Dainese et al., 2019). Crop and livestock diversification also enhances biodiversity by creating a habitat for beneficial insects, improving natural pest control, and reducing the need for chemical inputs. The integration of livestock adds another layer of ecological benefits, as animal manure contributes to nutrient cycling and enhances soil fertility. As reported in the qualitative findings, these practices collectively increase the system's resilience to environmental stresses, promote ecosystem balance, and improve the efficiency of water use (Zenda & Rudolph, 2024).

Despite the positive outcomes associated with agroecological practices, the findings revealed several barriers to their widespread adoption. One of the key challenges was the lack of extension services and technical support for farmers, particularly in rural areas where access to information and resources is limited. The issue of labor shortages was also recurring theme in both the case studies and qualitative findings. The case studies highlighted how labor-intensive practices, such as composting, mulching, and constructing soil conservation structures such as terraces and zai pits, placed a significant burden on farmers, often hindering widespread adoption. For example, in Burkina Faso and Tanzania, these practices were reported to improve soil fertility and crop yields, yet their labor demands proved to be a major barrier to long-term sustainability. This was consistent with the qualitative insights, where respondents noted that many agroecological practices, such as bokashi composting and fertility beds, required substantial physical effort and time, making them difficult to implement, especially for resource-constrained smallholders.These insights suggest that addressing labor shortages, perhaps through policy interventions or cooperative labor schemes, could significantly improve the viability of agroecological practices across Africa.

The findings also indicated that farmers often face significant economic barriers when transitioning to agroecological practices, primarily due to the high upfront costs associated with adopting these sustainable methods. Implementing practices such as crop diversification, organic fertilization, and integrated livestock management can require considerable financial investment, which can be a deterrent for many smallholder farmers. In addition, the lack of access to markets for organic and agroecological products can further compound the problem, as farmers are unable to secure premium prices to offset the initial costs. Without well-established supply chains and consumer demand for organic products, many farmers struggle to achieve profitability during the early stages of transitioning to agroecology. Qualitative findings points out that many farmers are still dependent on government subsidies for chemical fertilizers, which discourages the adoption of sustainable alternatives. This aligns with a wider understanding that the policy environment in many African countries, where conventional farming methods are often prioritized over agroecological approaches.
These barriers highlight the need for supportive policies, financial incentives, and improved market access to make agroecological farming a viable option for more farmers (Ayilara et al., 2023).

To promote the widespread adoption of agroecological practices, governments need to create enabling environments that support sustainable farming. This would include revising agricultural subsidy programs to incentivize the use of organic inputs and conservation techniques, as well as investing in training and extension services to equip farmers with the skills needed to implement agroecological practices. Future research should focus on addressing the existing gaps in the literature, particularly with regard to the long-term impacts of agroecological practices on soil health and farmer livelihoods. More longitudinal studies are needed to evaluate their sustainability over time and across diverse agroecological zones. Additionally, there is a need for more research on the economic viability of agroecology, particularly in terms of market access and the potential for scaling up organic farming systems (Mugiyo et al., 2021).

Alignment with Principles of Agroecology

Agroecology, as both a science and a movement, encompasses a set of guiding principles aimed at creating sustainable, resilient, and equitable food systems. The Healthy Soil Healthy Food (HSHF) initiative, spearheaded by the Alliance for Food Sovereignty in Africa (AFSA), embodies these principles through its focus on improving soil health, enhancing biodiversity, promoting sustainable agricultural practices, and empowering smallholder farmers across Africa. This section explores how the findings from the meta-analysis of case studies and success stories align with the 13 core principles of agroecology, showcasing practical examples of their application. Each principle is evaluated in terms of its role in fostering ecological resilience, socio-economic equity, and cultural preservation, with specific attention to the transformative impact of agroecological practices on communities.

1. Diversity

The first principle of agroecology focuses on diversity, which involves promoting biodiversity at genetic, species, and ecosystem levels. This is an important component of building resilience in farming systems. The meta-analysis demonstrates how agroecological practices are fostering crop diversity through the cultivation of a range of indigenous crops. An example from the qualitative findings highlights that smallholder farmers in South Africa, were trained in planting diverse local crops, which not only enhanced food security but also improved soil health through a greater variety of root systems that nourish the soil microbiota.

2. Synergies

Agroecology seeks to enhance synergies between different components of agroecosystems (plants, animals, soil, and water). The meta-analysis findings highlight several cases where farmers applied integrated crop-livestock systems, allowing synergies between these components. In Uganda, farmers were trained to integrate livestock into crop farming. The livestock provided manure, which was used to fertilize crops, while the crops fed the livestock, creating a mutually beneficial system (32). Additionally, integrating trees and shrubs into agricultural systems for agroforestry provides multiple ecosystem services such as nutrient cycling, water retention, and enhanced soil fertility.

3. Efficiency

Agroecological systems strive for efficiency by optimizing the use of locally available resources and reducing external inputs. The findings from the case studies showcase various examples where efficiency is achieved through reduced dependence on synthetic fertilizers and pesticides. In Zambia, the adoption of agroecological practices such as composting and the use of bio-fertilizers significantly reduced the need for expensive chemical inputs, improving the overall efficiency of farming systems (58). The promotion of biofertilizers such as Bokashi underpins this goal of reducing reliance on external synthetic fertilizers and enhancing natural nutrient cycles.

4. Resilience

The resilience principle highlights the importance of farming systems being able to withstand and recover from disturbances, including climate change. The meta-analysis supports the role of agroecology in building resilience, particularly in the face of climate variability in Africa. In Tanzania, agroecological practices such as mulching, intercropping, and agroforestry were shown to protect soils from erosion and improve water retention during drought periods. These practices were particularly beneficial for smallholder farmers in semi-arid regions, as they reduced vulnerability to erratic rainfall (13). The HSHF program's focus on climate adaptation aligns closely with this principle, as it promotes farming techniques that enhance the capacity of systems to adapt to environmental changes.

5. Recycling

Agroecology prioritizes recycling to close nutrient loops and improve soil health through the utilization of organic materials. The meta-analysis highlights success stories where recycling of organic matter played a pivotal role in restoring soil fertility. For example, in Kenya, the practice of returning crop residues to the soil, along with the use of animal manure and compost, significantly improved soil organic matter and overall fertility (21). These practices align with the HSHF initiative's advocacy for using locally sourced organic inputs rather than chemical fertilizers.

6. Co-creation and Sharing of Knowledge

Agroecology encourages co-creation and sharing of knowledge, especially between researchers, farmers, and indigenous communities. The HSHF project has been pivotal in fostering this exchange through farmer-to-farmer training, capacity building, and the establishment of knowledge-sharing platforms. Qualitative findings particularly highlight the success of peer learning approaches in Malawi, Uganda and South Africa, where experienced farmers trained others in agroecological techniques, thus creating a ripple effect that spread these practices across communities. The establishment of bio-input centers, as part of the HSHF initiative, further exemplifies the co-creation of knowledge by combining indigenous knowledge systems with modern science.

7. Human and Social Values

Agroecology places a strong emphasis on human and social values, promoting dignity, equity, and social well-being for farmers and communities. The meta-analysis findings highlight the importance of empowering smallholder farmers, particularly women and youth, who are often marginalized in conventional agricultural systems. For example, projects in Uganda, Burkina Faso and Togo specifically targeted women-led households for agroecological training, recognizing their crucial role in food production and household nutrition (34, 37, 51). The projects' focus on knowledge-sharing through community-driven programs also reinforces equity by ensuring that farmers have access to the same resources and learning opportunities, regardless of their socio-economic status. This aligns with the broader goal of social equity within agroecology, fostering inclusive development and social cohesion.

8. Culture and Food Traditions

The principle of culture and food traditions in agroecology acknowledges the importance of local cultures and culinary traditions in sustaining food systems. The meta-analysis identified success stories that supported the revival of indigenous crops and traditional farming techniques, which are deeply tied to cultural practices. In Kenya and South Africa, for instance, the promotion of traditional grains such as millet and sorghum enhanced dietary diversity and strengthened cultural identity (23, 44). These crops, traditionally grown by older generations, were being reintroduced to younger farmers, ensuring that cultural practices are passed down and preserved. This cultural revitalization is essential for maintaining food sovereignty, a key focus of agroecology as a whole.

9. Responsible Governance

The principle of responsible governance calls for inclusive and participatory decision-making processes in agricultural and food systems. The HSHF initiative fosters this principle by actively involving farmers, local communities, and policymakers in the development and implementation of agroecological practices. The meta-analysis reveals that in countries such as Uganda and Malawi, local farmers were directly involved in designing policies that support sustainable land management, such as setting up community-led bio-input centers (31, 48). The HSHF initiative also engages with governments to advocate for policies that support agroecological practices, ensuring that governance structures are responsive to the needs of smallholder farmers and community-based organizations. This participatory approach strengthens governance and helps ensure that agricultural policies are inclusive and equitable.

10. Circular and Solidarity Economy

The principle of the circular and solidarity economy highlights the importance of creating economies that are locally rooted, circular in nature, and based on solidarity among communities. The meta-analysis highlights examples where local economies have been bolstered by agroecological practices that promote resource recycling and local market development. In Senegal and Kenya, farmers have established local cooperatives to process and sell organic fertilizers produced from local waste, creating closed-loop systems that reduce external inputs while providing economic opportunities for smallholder farmers (24, 55). These cooperatives also foster solidarity by ensuring that profits are shared among community members, enhancing local economic resilience.

11. Land and Natural Resource Governance

Land and natural resource governance refers to equitable access to land and natural resources, which is critical for smallholder farmers. Essentially, all case studies contributed to supporting some form of community-driven approach to land management. One particular example was in Burkina Faso, through the creation of the Training Centre for Rural Developers of Guiè (CFAR), where young people were educated and empowered in sustainable agriculture and land management (38). The centre contributed to the sustainable management of natural resources through the promotion of soil regenerating agroecological practices, and ensuring that communities retained control. These efforts reflect agroecology's broader goal of fair land governance and the preservation of natural resources for future generations.

12. Resilience to Climate Change

Building resilience to climate change is one of the most urgent goals of agroecology, and the meta-analysis clearly demonstrates the effectiveness of agroecological practices in helping farmers adapt to increasingly unpredictable climates. In Kenya and Malawi, for example, agroforestry systems were implemented to provide shade, reduce soil erosion, and enhance water retention, which are critical adaptations in regions experiencing more frequent droughts (22, 47). Additionally, crop diversification through intercropping of drought-tolerant species has helped farmers maintain productivity even in adverse weather conditions. These practices align with the principle of resilience to climate change by equipping farmers with the tools they need to thrive in uncertain climatic conditions.

13. Health and Well-being

The principle of health and well-being underscores the connection between farming practices, food quality, and human health. Several case studies highlighted in the meta-analysis, particularly from Zambia, Kenya and Burkina Faso, show how the reduction of chemical inputs and the use of organic fertilizers and compost have improved soil health and resulted in nutrient-dense crops (21, 37, 58). This focus on soil health directly impacts human health, as healthier soils produce more nutritious food, helping to combat malnutrition and diet-related diseases.

Addressing Challenges

Farmers face numerous challenges when transitioning to agroecological practices. Yet despite these obstacles, many find the benefits of agroecology to be worth the effort and investment. Hence, with continued support and education, more farmers may be able to successfully transition to agroecological practices in the future. To address existing challenges several strategies can be implemented, as detailed in this section.

Labor Shortages

As indicated in the findings, agroecological practices often require more labor than conventional methods, creating challenges for smallholder farmers who may lack sufficient workforce. To address this issue, a multi-faceted approach is necessary. Investing in training programs can enhance the skill sets of local workers and attract new entrants into the agricultural sector, improving productivity and reducing dependency on external labor sources (OECD. 2023). Additionally, governments can implement policies that improve working conditions and wages in agriculture, making it a more attractive career choice, including promoting agricultural education and creating pathways for young people to enter the field(OECD. 2023). Farmers can also form cooperatives to share labor resources and reduce individual burdens, facilitating knowledge sharing and collective purchasing of inputs (Bottazzi et al. 2020).

Financial Constraints

The provisoon of low-interest loans or microfinance options specifically tailored for smallholder farmers can help them invest in necessary equipment and practices (Khan et al. 2024). Government and non-governmental organizations can also develop financial incentive programs that subsidize the costs of transitioning to agroecological practices, helping to mitigate risks associated with investments in new technologies (Blair, 2020). Establishing community-based funding mechanisms, such as revolving funds or grant programs, can also provide farmers with the financial support needed to implement sustainable practices without incurring significant debt (Khan et al. 2024).

Time and Patience Required

The long-term nature of agroecological practices can discourage farmers who seek immediate results. Implementing pilot projects that showcase the benefits of agroecological practices over time can help build trust and encourage adoption among skeptical farmers (Shelton, 2021). Encouraging farmers to start with small-scale implementations allows them to gradually observe benefits without fully committing all resources upfront, lowering perceived risk and building confidence in longer-term investments (Blair, 2020). Additionally, providing education about the cumulative benefits of agroecological practices—such as improved soil health and resilience—can help farmers understand the value of patience in their investments (Shelton, 2021).

Climatic Variability

Implementing agroecological techniques such as crop diversification, agroforestry, and improved water management can enhance resilience against climatic shocks. Investing in research to develop climate-resilient crop varieties and sustainable farming techniques is crucial, with collaborations between universities, research institutions, and farmers facilitating this process. Engaging local communities in identifying specific climatic challenges they face also allows for tailored adaptation strategies that leverage local knowledge and resources (Sinore & Wang, 2024).

Limited Access to Resources

FIndings highlighted thant access to necessary inputs is often limited for smallholder farmers. Establishing networks for sharing resources among farmers can improve access to essential inputs without significant financial investment, including initiatives such as seed banks or shared equipment programs (Blair, 2020). Governments can create programs that provide subsidized access to organic inputs or establish partnerships with suppliers to ensure availability at reasonable prices (Khan, et al. 2024). In addition, , training farmers on how to produce their own organic inputs (e.g., composting) or manage resources sustainably can reduce dependency on external suppliers (Khan et al. 2024).

Lack of Technical Knowledge and Support

To enhance farmers' technical knowledge and support, strengthening agricultural extension services is crucial, with the utilization of information and communication technologies (ICTs) facilitating the dissemination of knowledge tailored to farmers' needs. For instance, mobile apps and online platforms can provide timely information on best practices, pest management, and crop rotation. Establishing farmer field schools or peer learning groups enables farmers to share experiences and learn from one another, fostering trust and enhancing the practical application of new techniques through this participatory approach. Additionally, implementing systems that allow farmers to provide feedback on training can improve engagement and ensure that the information provided is relevant and actionable. (J-PAL, 2023).

Cultural and Social Barriers

Addressing cultural and social barriers in agroecological practices requires a nuanced approach that considers gender dynamics and traditional values. Promoting gender equity in agricultural practices can empower women farmers, who often face discrimination. Programs that specifically target women's access to resources, training, and decision-making can help mitigate these inequalities. Simultaneously, marketing strategies for traditional foods should emphasize their nutritional benefits and cultural significance. Educational campaigns can help shift perceptions and reduce stigma associated with these foods, encouraging broader acceptance within communities (Ume et al. 2023).

Policy Challenges

To navigate policy challenges favoring conventional farming, farmers and organizations can engage in advocacy to influence policy changes that support agroecological practices, including lobbying for subsidies or incentives for sustainable farming methods. Simultaneously, policymakers should involve farmers in the development of agricultural policies to ensure that their needs and perspectives are considered. This participatory approach can lead to more effective policies that promote agroecology (Gemmill-Herren et al. 2023).

Certification Difficulties

Overcoming the challenges of organic certification for smallholder farmers requires streamlining the certification process, which can reduce costs and complexity. Policies that recognize local practices as valid forms of organic farming can further facilitate this process. Complementing these efforts, government or NGO-led initiatives can provide financial assistance or technical support to help farmers meet certification standards. Additionally, training programs focused on organic farming practices can prepare farmers for certification requirements. This integrated approach aims to make organic certification more accessible and achievable for smallholder farmers, enabling them to benefit from the market advantages of certified organic products while maintaining sustainable agroecological practices (Ume et al. 2023).

Scaling Issues

To address obstacles in scaling successful agroecological practices, farmers can join forces through collaborative scaling initiatives, such as cooperatives or community groups, to pool resources, share knowledge, and disseminate best practices more effectively. This collective strategy can significantly boost the adoption of successful methods across wider areas. Simultaneously, conducting research to identify scalable, context-specific agroecological practices is crucial for tailoring solutions to local conditions, with the sharing of successful case studies serving to inspire broader adoption. Developing markets specifically for agroecologically produced goods can also provide strong incentives for farmers to scale up their practices. Creating supply chains that directly connect smallholders with consumers can enhance market access and improve profitability, further encouraging the expansion of agroecological methods (Nicol, 2020).

Water Scarcity

Rainwater harvesting techniques, such as constructing ponds or cisterns to collect and store rainwater, can provide a vital water source during dry periods, conserving water and enhancing soil moisture levels to promote better crop yields (Slow Food, 2023). Adopting efficient irrigation techniques like drip irrigation and sprinkler systems can optimize water use and minimize waste, delivering water directly to plant roots - a particularly beneficial approach in arid regions where water is limited (Sentlinger, n.d.). Additionally, implementing soil management practices such as mulching and cover cropping can significantly improve soil moisture retention, reducing evaporation and maintaining more stable moisture levels in the soil (Slow Food, 2023).

Soil Degradation and Salinization

Conservation agriculture practices, including reduced tillage, crop rotation, and maintaining vegetative cover, can help restore soil health by improving soil structure, enhancing organic matter content, and increasing biodiversity within the soil ecosystem (Lal, 2015). Complementing this approach, integrated nutrient management utilizing organic fertilizers and biofertilizers can enhance soil fertility while reducing reliance on chemical inputs, improving nutrient availability and mitigating salinity issues by promoting healthier microbial communities in the soil (Lal, 2015). Farmers can also adopt specific salinity management techniques such as leaching (applying excess water to wash away salts) and selecting salt-tolerant crop varieties to combat salinity issues effectively (Akanmu et al. 2023).

Limited Research and Funding

To overcome the lack of research and funding in agroecology, farmers can engage in collaborative research initiatives with universities and research institutions can facilitate access to innovative agroecological practices tailored for specific regional challenges, while also attracting funding for pilot projects. Complementing this, adopting participatory research approaches that involve farmers in the research process ensures that studies address practical challenges they face, leading to more relevant findings and increased adoption of successful practices (Akanmu et al. 2023). Farmers' organizations can also play a key role by advocating for greater public investment in agroecological research, particularly in arid regions where such practices are vital for sustainability.

Maintenance of Practices

Sustaining agroecological practices over time requires a multifaceted approach that combines education, community support, and incentives. Continuous education and training programs for farmers can reinforce knowledge about best practices and new techniques, with access to local workshops or online resources supporting ongoing learning (Akanmu et al. 2023). Establishing community support networks, such as local support groups or cooperatives, allows farmers to share resources, labor, and knowledge, helping to maintain practices through mutual assistance during peak labor times or when facing challenges (Akanmu et al. 2023). Government or NGO-led incentive programs that provide financial benefits for maintaining sustainable practices can also encourage long-term commitment from farmers, including subsidies for organic inputs or payments for ecosystem services.

Market Access

Direct marketing approaches, such as farmers' markets, community-supported agriculture (CSA) programs, or online platforms, can allow farmers to capture a larger share of the retail price while building relationships with consumers (Akanmu et al. 2023). Supporting these efforts, certification support programs can assist smallholder farmers in accessing premium markets by providing training on certification requirements and financial support for related costs(Akanmu et al. 2023). Additionally, building value chains through collaboration with local businesses can connect agroecological producers with processors and retailers, enhancing market access. This includes developing partnerships that promote local sourcing of ingredients from agroecological farms[4]. By integrating these direct marketing, certification support, and value chain development strategies, farmers can create more robust and diverse market opportunities for their agroecologically produced goods.

Study Limitations

This meta-analysis revealed several limitations in the included studies that warrant consideration when interpreting the findings. The variability in study designs, ranging from field trials to participatory research, introduced challenges in synthesizing results due to differing levels of rigor and reliability. Many studies lacked control groups, making it difficult to attribute observed changes solely to the agroecological practices under investigation.

Geographical and climatic biases were also evident, with certain regions, such as East Africa, being overrepresented. This uneven distribution may skew results towards conditions specific to those areas, limiting the generalizability of findings across the African continent. Furthermore, studies conducted in specific climatic conditions may not be representative of broader ecological zones within the target countries, potentially leading to over- or underestimation of the effectiveness of certain practices in different climates. The inconsistent measurement of outcomes across studies posed another challenge, as the wide range of indicators used for soil health, crop yields, and socio-economic outcomes made direct comparisons difficult. Lastly, the reliance on self-reported data from farmers in some studies may have introduced reporting bias or inaccuracies, particularly in areas such as crop yields or income levels.

Conclusion

This meta-analysis examined the impact of agroecological practices on soil health in 11 Sub-Saharan African countries. The analysis reviewed 61 case studies and four key informant interviews, exploring the benefits, challenges, and broader impacts of agroecology in diverse African contexts. The findings provide compelling evidence that agroecological practices can significantly improve soil health, enhance agricultural productivity, and contribute to improved livelihoods for smallholder farmers.

Specifically, the analysis revealed enhanced soil health can be achieved through agroecological practices such as organic manure application, agroforestry, mulching, and intercropping. These practices consistently demonstrated positive impacts on soil health indicators, increasing organic matter content, improving soil structure, enhancing nutrient availability, and fostering beneficial microbial activity. The improved soil health directly translated to increased agricultural productivity, as evidenced by higher crop yields and livestock production in numerous case studies. The integration of agroecological techniques contributed to this increase by enhancing soil fertility, improving water retention, and promoting biodiversity.

The adoption of agroecological practices had positive cascading effects on farmers' livelihoods. Increased yields led to improved food security, and better nutrition outcomes. The reduced reliance on external inputs, such as chemical fertilizers, also translated to cost savings for farmers. Some farmers were also able to generate income by selling surplus produce or producing and selling organic inputs.

Despite the positive findings, significant challenges were also highlighted that hinder the widespread adoption and scaling up of agroecological practices. These included limited extension services and technical support, with a recurring issue being the lack of adequate services to provide farmers with the knowledge and skills needed to implement agroecological practices effectively. Labor shortages posed another significant barrier, as many agroecological practices proved to be labor-intensive, particularly affecting women who often bear the brunt of agricultural labor.

Financial constraints also emerged as a major challenge, as transitioning to agroecological farming often requires upfront investments that many farmers are unable to afford. This is compounded by limited access to markets for agroecological products, preventing farmers from securing premium prices that could offset these initial costs. Farmer perceptions presented an additional hurdle, with many perceiving agroecological practices as less effective than conventional methods, primarily due to a lack of awareness and the prevalence of government-subsidized chemical inputs.

Recommendations

Policy and Subsidy Reform

Governments should revise existing agricultural subsidy programs to prioritize agroecological practices over conventional, chemical-intensive methods. Subsidies should provide incentives for the use of organic inputs and conservation techniques, thereby lowering the financial barriers for farmers transitioning to agroecology. This could involve zero tariffs or direct financial support for organic farming inputs, equipment, and labor-sharing initiatives.

Capacity Building and Extension Services

There is an urgent need to invest in training and extension services that equip farmers with the knowledge and skills necessary for agroecological practices. Training programs should focus on practical applications, making them more accessible, especially to rural farmers. This can be supplemented with knowledge-sharing platforms that allow for peer-to-peer learning and the dissemination of best practices.

Market Development and Access

Governments and NGOs should work together to establish stronger markets for organic and agroecological products. This can be achieved through certification programs, labeling initiatives, and the creation of value chains that connect producers with consumers who prioritize sustainable and organic products. Moreover, the African Continental Free Trade Area (AfCFTA) should include provisions to enhance cross-border trade in organic inputs and goods, thus opening up new markets for agroecological farmers.

Support for Cooperative Labor Models

Given the labor-intensive nature of many agroecological practices, cooperative models that allow farmers to pool labor resources should be explored. Governments and development organizations could support the establishment of cooperative groups that share labor for activities such as terrace construction, composting, and soil conservation. Such schemes would help alleviate the labor burden on individual smallholders and facilitate broader adoption.

Research and Data Gaps

Future research should focus on addressing gaps in the long-term impacts of agroecological practices on soil health, crop yields, and farmer livelihoods. Longitudinal studies across different agroecological zones can contribute to a better understanding of the sustainability of these practices over time. More research is also needed on the economic viability of agroecological systems, in particular their potential to enhance food security and reduce poverty at scale.

Incorporation of Agroecology in National Agricultural Strategies

Governments should integrate agroecology into their national agricultural policies and strategies as a means of achieving food security, climate resilience, and environmental sustainability. This would involve the further alignment of national strategies with international frameworks such as the African Union's CAADP and the Sustainable Development Goals (SDGs). The promotion of agroecology as a climate adaptation strategy should also be highlighted in policy discourse.

References

5. Akanmu AO, Akol AM, Ndolo DO, Kutu FR and Babalola OO. 2023. Agroecological techniques: adoption of safe and sustainable agricultural practices among the smallholder farmers in Africa. Front. Sustain. Food Syst. 7:1143061. doi: 10.3389/fsufs.2023.1143061

6. Amede, T., Konde, A.A., Muhinda, J.J., Bigirwa, G., 2023. Sustainable Farming in Practice: Building Resilient and Profitable Smallholder Agricultural Systems in Sub-Saharan Africa. Sustainability 15, 5731. https://doi.org/10.3390/su15075731

7. Amundson, R., Berhe, A.A., Hopmans, J.W., Olson, C., Sztein, A.E., Sparks, D.L., 2015. Soil and human security in the 21st century. Science 348, 1261071. https://doi.org/10.1126/science.1261071

8. Ayilara, M.S., Adeleke, B.S., Akinola, S.A., Fayose, C.A., Adeyemi, U.T., Gbadegesin, L.A., Omole, R.K., Johnson, R.M., Uthman, Q.O., Babalola, O.O., 2023. Biopesticides as a promising alternative to synthetic pesticides: A case for microbial pesticides, phytopesticides, and nanobiopesticides. Front Microbiol 14, 1040901. https://doi.org/10.3389/fmicb.2023.1040901

9. Blair, E., 2020. Overcoming barriers to agroecological practices: Assessing the role of financial incentive programs in facilitating cover crop adoption. Master of Science, School for Environment and Sustainability, University of Michigan https://deepblue.lib.umich.edu/bitstream/handle/2027.42/162595/Blair_Erica_Thesis.pdf?sequence=1

10. Bottazzi, P., Boillat, S., Marfurt, F., Seck, S.M., 2020. Channels of Labour Control in Organic Farming: Toward a Just Agroecological Transition for Sub-Saharan Africa. Land 9, 205. https://doi.org/10.3390/land9060205

11. Dainese, M., Martin, E.A., Aizen, M.A., Albrecht, M., Bartomeus, I., Bommarco, R., Carvalheiro, L.G., Chaplin-Kramer, R., Gagic, V., Garibaldi, L.A., Ghazoul, J., Grab, H., Jonsson, M., Karp, D.S., Kennedy, C.M., Kleijn, D., Kremen, C., Landis, D.A., Letourneau, D.K., Marini, L., Poveda, K., Rader, R., Smith, H.G., Tscharntke, T., Andersson, G.K.S., Badenhausser, I., Baensch, S., Bezerra, A.D.M., Bianchi, F.J.J.A., Boreux, V., Bretagnolle, V., Caballero-Lopez, B., Cavigliasso, P., Ćetković, A., Chacoff, N.P., Classen, A., Cusser, S., da Silva E Silva, F.D., de Groot, G.A., Dudenhöffer, J.H., Ekroos, J., Fijen, T., Franck, P., Freitas, B.M., Garratt, M.P.D., Gratton, C., Hipólito, J., Holzschuh, A., Hunt, L., Iverson, A.L., Jha, S., Keasar, T., Kim, T.N., Kishinevsky, M., Klatt, B.K., Klein, A.-M., Krewenka, K.M., Krishnan, S., Larsen, A.E., Lavigne, C., Liere, H., Maas, B., Mallinger, R.E., Martinez Pachon, E., Martínez-Salinas, A., Meehan, T.D., Mitchell, M.G.E., Molina, G.A.R., Nesper, M., Nilsson, L., O'Rourke, M.E., Peters, M.K., Plećaš, M., Potts, S.G., Ramos, D. de L., Rosenheim, J.A., Rundlöf, M., Rusch, A., Sáez, A., Scheper, J., Schleuning, M., Schmack, J.M., Sciligo, A.R., Seymour, C., Stanley, D.A., Stewart, R., Stout, J.C., Sutter, L., Takada, M.B., Taki, H., Tamburini, G., Tschumi, M., Viana, B.F., Westphal, C., Willcox, B.K., Wratten, S.D., Yoshioka, A., Zaragoza-Trello, C., Zhang, W., Zou, Y., Steffan-Dewenter, I., 2019.

A global synthesis reveals biodiversity-mediated benefits for crop production. Sci Adv 5, eaax0121. https://doi.org/10.1126/sciadv.aax0121

12. FAO. 2023. Sustainable soil management as a keystone of nutrition sensitive agriculture in Burkina Faso. Country Fact Sheet. Food and Agriculture Organization of the United Nations. https://openknowledge.fao.org/server/api/core/bitstreams/6c37b5c6-0e76-40f0-a028-fd043c0bf0ba/content

13. Gemmill-Herren, B., Gottwald, F.-T., Batello, C., Bezner Kerr, R., Herren, H.R., 2023. Editorial: Agroecology in policy and practice. Front. Sustain. Food Syst. 7. https://doi.org/10.3389/fsufs.2023.1136305

14. Khan, F.U., Nouman, M., Negrut, L., Abban, J., Cismas, L.M., Siddiqi, M.F., 2024. Constraints to agricultural finance in underdeveloped and developing countries: a systematic literature review. International Journal of Agricultural Sustainability 22, 2329388. https://doi.org/10.1080/14735903.2024.2329388

15. Kopittke, P.M., Minasny, B., Pendall, E., Rumpel, C., McKenna, B.A., 2024. Healthy soil for healthy humans and a healthy planet. Critical Reviews in Environmental Science and Technology 54, 210–221. https://doi.org/10.1080/10643389.2023.2228651

16. Lal, R., 2015. Restoring Soil Quality to Mitigate Soil Degradation. Sustainability 7, 5875–5895. https://doi.org/10.3390/su7055875

17. Mugiyo, H., Chimonyo, V.G.P., Sibanda, M., Kunz, R., Masemola, C.R., Modi, A.T., Mabhaudhi, T., 2021. Evaluation of Land Suitability Methods with Reference to Neglected and Underutilised Crop Species: A Scoping Review. Land (Basel) 10, 125. https://doi.org/10.3390/land10020125

18. Nicol, P., 2020. Pathways to Scaling Agroecology in the City Region: Scaling out, Scaling up and Scaling deep through Community-Led Trade. Sustainability 12, 7842. https://doi.org/10.3390/su12197842

19. OECD. 2023. Labour and skills shortages in the agro-food sector. OECD Food, Agriculture and Fisheries Papers, 17 January 2023. https://www.oecd.org/en/publications/2023/01/labour-and-skills-shortages-in-the-agro-food-sector_c9915f4e.html.

20. Sentlinger K. n.d. Water Scarcity and Agriculture. The Water Project. https://thewaterproject.org/water-scarcity/water-scarcity-and-agriculture.

21. Shelton S. 2021. Agroecology: A key piece to climate adaptation & mitigation? CGIAR, Climate Change, Agriculture amd Food Security (CCAFS) https://ccafs.cgiar.org/news/agroecology-key-piece-climate-adaptation-mitigation.

22. Sinore, T., Wang, F., 2024. Impact of climate change on agriculture and adaptation strategies in Ethiopia: A meta-analysis. Heliyon 10, e26103. https://doi.org/10.1016/j.heliyon.2024.e26103

23. Slow Food, 2023. Slow Food on World Food Day: Agroecology practices as the solution to the water crisis and to guarantee food security https://www.slowfood.com/blog-and-news/slow-food-on-world-food-day-agroecology-practices-as-the-solution-to-the-water-crisis-and-to-guarantee-food-security/

24. Souissi, A., Dhehibi, B., Oumer, A.M., Mejri, R., Frija, A., Zlaoui, M., Dhraief, M.Z., 2024. Linking farmers' perceptions and management decision toward sustainable agroecological transition: evidence from rural Tunisia. Front Nutr 11, 1389007. https://doi.org/10.3389/fnut.2024.1389007

25. The Abdul Latif Jameel Poverty Action Lab (J-PAL). 2023. Improving agricultural information and extension services to increase small-scale farmer productivity. https://www.povertyactionlab.org/policy-insight/improving-agricultural-information-and-extension-services-increase-small-scale.

26. Ume, C.O., Onah, O.G., Okpukpara, B.C., Chukwuma-Ume, N., Charles, U.I., Omeje, E.E., Chiemela, C.J., Chituru, I.J., Orazulike, O., 2023. Factors influencing smallholder adoption of organic agriculture in Southeast geopolitical region of Nigeria. Front. Sustain. Food Syst. 7. https://doi.org/10.3389/fsufs.2023.1173043

27. Zenda, M., Rudolph, M., 2024. A Systematic Review of Agroecology Strategies for Adapting to Climate Change Impacts on Smallholder Crop Farmers' Livelihoods in South Africa. Climate 12, 33. https://doi.org/10.3390/cli12030033

28. Zingore, S; Mutegi, J; Agesa, B; Desta, LT; Kihara, J. 2015. Soil degradation in sub-Saharan Africa and crop production options for soil rehabilitation. Better Crops with Plant Food 99 (1): 24-26.

Appendix 1: Case Studies (highlighted case studies were not from the AFSA database)

Zimbabwe

1. Mpofu E.. Zimbabwean Farmers Revive Stagnant Farms Through Agroecology. https://afsafrica.org/wp-content/uploads/2020/11/zimsoff-2.pdf
2. Mukute M.. Zimbabwe Farmer-Innovators Quietly Define Food Sovereignty. https://afsafrica.org/wp-content/uploads/2019/04/zimbabwe-farmer-innovators.pdf
3. Mupetesi M., Mupetesi T.. Community Conservation of Land and Sustainable Utilization of Biodiversity in Zimbabwe. https://afsafrica.org/wp-content/uploads/2019/04/community-conservation-a4-1.pdf
4. Mudzingwa N.. Shashe AgroEcology School for Farmer-to-Farmer Training, Zimbabwe. https://afsafrica.org/wp-content/uploads/2019/02/03_shashe-zimbabwe-new.pdf
5. The Oakland Institute, Alliance for Food Sovereignty in Africa (AFSA). Mulch and Seed Banks: Conservation Farming in Zimbabwe. https://afsafrica.org/wp-content/uploads/2019/04/mulch-and-seed-banks-zimbabwe.pdf
6. The Seed Knowledge Initiative Agroecology Landscape Barefoot Guide Writer's Collective. Viyani's Story: Managing livestock grazing to regenerate land and rivers. https://www.seedandknowledge.org/wp-content/uploads/2021/08/BFG-Landscape-Chapter-3-The-Lamenting-is-Over-lores.pdf
7. Tadele, K. (n.d.). Reviving Resilience: Chimanimani's Journey from Cyclone Devastation to Sustainable Recovery. https://afsafrica.org/reviving-resilience-chimanimanis-journey-from-cyclone-devastation-to-sustainable-recovery/
8. The Oakland Institute, Alliance for Food Sovereignty in Africa (AFSA). Agro-Ecology and Water Harvesting in Zimbabwe. https://afsafrica.org/wp-content/uploads/2019/04/water_harvesting_zimbabwe.pdf
9. The Oakland Institute, Alliance for Food Sovereignty in Africa (AFSA). Agroecology for Home and Market: A Winning Combination for Rural Communities in Mashonaland East, Zimbabwe. https://afsafrica.org/wp-content/uploads/2019/04/gardenafrica_web.pdf
10. Muchini, B. Holistic Land and Livestock Management in Manicaland. https://afsafrica.org/wp-content/uploads/2019/04/holistic-land-and-livestock-a4-1.pdf

Tanzania

11. Lwanga C.. Exploring the Heart of Agroecology Transition in Tanzania: A firsthand account from the AFSA's HSHF officer. https://afsafrica.org/exploring-the-heart-of-agroecology-transition-in-tanzania-a-first-hand-account-from-the-afsas-hshf-officer/
12. Santoso, M.V., Bezner Kerr, R.N., Kassim, N., Martin, H., Mtinda, E., Njau, P., Mtei, K., Hoddinott, J., Young, S.L., 2021. A Nutrition-Sensitive Agroecology Intervention in Rural Tanzania Increases Children's Dietary Diversity and Household Food Security But Does Not Change Child

Anthropometry: Results from a Cluster-Randomized Trial. J Nutr 151, 2010–2021. https://doi.org/10.1093/jn/nxab052
13. The Oakland Institute, Alliance for Food Sovereignty in Africa (AFSA). Conservation Agriculture in Tanzania. https://afsafrica.org/wp-content/uploads/2019/04/conservation_agriculture_tanzania.pdf
14. The Oakland Institute, Alliance for Food Sovereignty in Africa (AFSA). Growing Organic Pineapples in Tanzania. https://afsafrica.org/wp-content/uploads/2019/04/organic_pineapples_tanzania.pdf
15. Milheiras, S.G., Sallu, S.M., Loveridge, R., Nnyiti, P., Mwanga, L., Baraka, E., Lala, M., Moore, E., Shirima, D.D., Kioko, E.N., Marshall, A.R., Pfeifer, M., 2022. Agroecological practices increase farmers' well-being in an agricultural growth corridor in Tanzania. Agron Sustain Dev 42, 56. https://doi.org/10.1007/s13593-022-00789-1
16. Silungwe F.R.. Soil and Water Conservation Practices Strengthen Harvests in Tanzania Highlands. https://afsafrica.org/wp-content/uploads/2020/12/sua.pdf
17. The Oakland Institute, Alliance for Food Sovereignty in Africa (AFSA). Soil and Water Conservation on the Slopes of Kilimanjaro. https://afsafrica.org/wp-content/uploads/2019/04/soil_water_conservation_kilimanjaro_tanzania.pdf

Kenya

18. Karuga, J.G., 2022. Agroecological farming impacts on livelihoods improvement to inform county government on enactment of agroecology policy : case study of Kiambu County, Central Kenya (Master thesis). Norwegian University of Life Sciences, Ås. https://nmbu.brage.unit.no/nmbu-xmlui/handle/11250/2995687
19. Kariuki D.N.. Changing the Fortunes of Farmers and Families in Murang'a County, Kenya. https://afsafrica.org/wp-content/uploads/2020/12/oack-compressed.pdf
20. Maina A. BIBA Kenya Champions Sustainable Agriculture in Nakuru: A Beacon of Hope and Resilience Amidst Challenges. https://afsafrica.org/wp-content/uploads/2023/12/biba-kenya-champions-sustainable-agriculture-in-nakuru-a-beacon-of-hope-and-resilience-amidst-challenges-1.pdf
21. Nderitu S.. Organic and Soil Fertility Practices Bring Food and Livelihood Security to Farmers in Central Kenya. https://afsafrica.org/wp-content/uploads/2019/02/03_central-kenya.pdf
22. Righa M. Kenyan Farmers Triumph Over Climate Adversity with Agroecological Practices. https://afsafrica.org/wp-content/uploads/2024/01/kenyan-farmers-triumph-over-climate-adversity-with-agroecological-practices-p.pdf
23. Wafula F.. Food Forests in Kenya are Using Modern Forestry Techniques to Create Food Sovereignty and Security. https://afsafrica.org/wp-content/uploads/2021/02/biogi_compressed.pdf
24. Wafula F.. Reviving dead soils: A hidden treasure for healthy food in Kenya. https://afsafrica.org/wp-content/uploads/2023/12/hshfa-success-stories-_compressed.pdf
25. Bett, E. (n.d.). Biofertilizers tackling climate change in Kiambu, Kenya. Resources Oriented Development Initiatives. https://afsafrica.org/wp-content/uploads/2023/12/hshfa-success-stories-_compressed.pdf
26. Belmain S.R., Stevenson P.C.. Using Pesticidal Plants for Pest Management in Africa. https://afsafrica.org/wp-content/uploads/2019/04/using-pesticidal-plants-for-pest-management-in-africa.pdf
27. Kuria S.. Turning Arid Lands into Breadbaskets: Rehema Farm's Journey to Feed Africa. https://afsafrica.org/wp-content/uploads/2024/01/turning-arid-lands-into-breadbaskets-rehema-farms-journey-to-feed-africa.pdf
28. The Oakland Institute, Alliance for Food Sovereignty in Africa (AFSA). Biological Pest Control: Push-Pull in East Africa. https://afsafrica.org/wp-content/uploads/2019/04/push_pull_kenya.pdf
29. The Seed Knowledge Initiative Agroecology Landscape Barefoot Guide Writer's Collective. Chipo's Story: Farming naturally in Julius Astiva's food forest. https://www.seedandknowledge.org/wp-content/uploads/2021/08/BFG-Landscape-Chapter-3-The-Lamenting-is-Over-lores.pdf
30. The Oakland Institute, Alliance for Food Sovereignty in Africa (AFSA). Biointensive Agriculture Training Program in Kenya. https://afsafrica.org/wp-content/uploads/2019/04/biointensive_agriculture_kenya.pdf

Uganda

31. Kiirya P.D. Busaino Fruits and Herbs: A Green Oasis Transforming Uganda's Agroecology Landscape. https://afsafrica.org/wp-content/uploads/2023/12/busaino-fruits-and-herbs-a-green-oasis-transforming-ugandas-agroecology-landscape-1.pdf
32. Obin B.E.. Restoring Community Farmland in Uganda. https://afsafrica.org/wp-content/uploads/2020/12/kafscul-compressed.pdf
33. Nyanzi S.. A Revolutionary Farming Blueprint: Plant Every Day to Harvest Every Day. https://afsafrica.org/wp-content/uploads/2023/12/a-revolutionary-farming-blueprint-plant-every-day-to-harvest-every-day-1.pdf
34. Tumuhe C. Empowering Women and Youth: The Inspiring Story of KSAM Farm. https://afsafrica.org/empowering-women-and-youth-the-inspiring-story-of-ksam-farm/
35. Tumuhe C., Ahmad A. Agroecology in Uganda: A firsthand account by a student researcher from the Institute of Development Studies. https://afsafrica.org/agroecology-in-uganda-a-firsthand-account-by-aishah-a-student-researcher-from-the-institute-of-development-studies-ids/

Burkina Faso

36. The Oakland Institute, Alliance for Food Sovereignty in Africa (AFSA). Soil and Water Conservation Techniques in Burkina Faso. https://afsafrica.org/wp-content/uploads/2019/04/soil_water_conservation_burkina_faso.pdf
37. The Oakland Institute, Alliance for Food Sovereignty in Africa (AFSA). Women's Association for Compost and Other Agroecological Practices in Burkina Faso. https://afsafrica.org/wp-content/uploads/2019/04/compost_burkina_faso.pdf
38. Alliance for Food Sovereignty in Africa. (n.d.). Reclaiming Life in Marginal Areas and Fragile Ecosystems through Innovative Solutions: The Case of Bocage Perimeters in Burkina Faso. https://afsafrica.org/wp-content/uploads/2019/04/reclaiming-life-in-marginal-areas.pdf
39. The Oakland Institute, Alliance for Food Sovereignty in Africa (AFSA). Organic Cotton Production in West Africa. https://afsafrica.org/wp-content/uploads/2019/04/organic_cotton_west_africa.pdf
40. The Oakland Institute, Alliance for Food Sovereignty in Africa (AFSA). The West African Integrated Production and Pest Management Program (IPPM). https://afsafrica.org/wp-content/uploads/2019/04/integrated_production_pest_management_west_africa.pdf
41. The Seed Knowledge Initiative Agroecology Landscape Barefoot Guide Writer's Collective. Thembi's Story: FMNR reaches out across huge areas in West Africa. https://www.seedandknowledge.org/wp-content/uploads/2021/08/BFG-Landscape-Chapter-3-The-Lamenting-is-Over-lores.pdf

South Africa

42. Stuart, L.M., n.d. Agroecology in Practice: A case study of five community gardens in Msinga, South Africa. Dissertation: MSc Sustainable Horticulture and Food Production Schumacher College and Plymouth University.
43. Gibson, W.A., 2016. Agro-ecological and Conservation Agriculture principles to assist large-scale dryland sugarcane farmers in the KwaZulu-Natal Midlands South region to improve soil quality. Dissertation: MPhil Sustainable Development in the Faculty of Economic and Management Sciences at Stellenbosch University.
44. Strachan, B.D., 2014. The design, implementation and assessing of an agroecological cropping system by rural KwaZulu-Natal households : its effect on their diet and food security. Dissertation: MPhil Sustainable Development in the Faculty of Economic and Management Sciences at Stellenbosch University.

45. Walker, S., Kau, J.S., Collett, A., Myeni, L.M., Koatla, T.A.B., Qwabe, C.N.C., Khwene, M.M., 2024. Using Case Studies to Develop an Agro-ecological Management Framework for South Africa.

Malawi

46. The Oakland Institute, Alliance for Food Sovereignty in Africa (AFSA). Legume Diversification to Improve Soil Fertility in Malawi. https://afsafrica.org/wp-content/uploads/2019/04/legume_malawi.pdf
47. The Oakland Institute, Alliance for Food Sovereignty in Africa (AFSA). (n.d.) Agroforestry for Food Security in Malawi. https://afsafrica.org/wp-content/uploads/2019/04/food_security_malawi.pdf
48. Nordin K., Nordin S. 2014. Never Ending Food in Malawi. https://afsafrica.org/wp-content/uploads/2015/11/Never-Ending-Food-in-Malawi.pdf
49. Belmain S.R., Stevenson P.C.. Using Pesticidal Plants for Pest Management in Africa. https://afsafrica.org/wp-content/uploads/2019/04/using-pesticidal-plants-for-pest-management-in-africa.pdf
50. The Seed Knowledge Initiative Agroecology Landscape Barefoot Guide Writer's Collective. Chifundo's Story: Using permaculture to reimagine the land. https://www.seedandknowledge.org/wp-content/uploads/2021/08/BFG-Landscape-Chapter-3-The-Lamenting-is-Over-lores.pdf

Togo

51. Kuadjoviayedeu E.E.M. 2004. Agroecological Training on Biofertilisers Improves Women's Livelihoods in Togo. https://afsafrica.org/wp-content/uploads/2020/12/yve_compressed.pdf
52. The Oakland Institute, Alliance for Food Sovereignty in Africa (AFSA). (n.d.). Improving Traditional Systems of Soil Fertility to Increase Quality-Agricultural Production in the Savannah Region of Togo (Oti and Tandjoaré Districts). https://afsafrica.org/wp-content/uploads/2019/04/improving-traditional-systems-of-soil-fertility-.pdf
53. Nenonéné Jérémie G.K. Agroecology Farmers More Resilient in the Face of The Rising Prices of Agricultural Inputs. https://afsafrica.org/wp-content/uploads/2023/12/agroecology-farmers-more-resilient-in-the-face-of-the-rising-prices-of-agricultural-inputs.pdf

Senegal

54. Boillat, S., Belmin, R., Bottazzi, P., 2022. The agroecological transition in Senegal: transnational links and uneven empowerment. Agric Hum Values 39, 281–300. https://doi.org/10.1007/s10460-021-10247-5
55. The Oakland Institute, Alliance for Food Sovereignty in Africa (AFSA). Overcoming the Constraints of Agriculture in the Sahel by Successful Community-Based Approaches: The Case of the Regeneration of Land and the Fight Against Soil Salinization in the Groundnut Basin in Senegal. https://afsafrica.org/wp-content/uploads/2019/04/overcoming-the-constraints-of-agriculture-.pdf
56. The Oakland Institute, Alliance for Food Sovereignty in Africa (AFSA). Regenerative Agriculture in Senegal. https://afsafrica.org/wp-content/uploads/2019/04/regenerative_agriculture_senegal.pdf
57. The Oakland Institute, Alliance for Food Sovereignty in Africa (AFSA). The West African Integrated Production and Pest Management Program (IPPM). https://afsafrica.org/wp-content/uploads/2019/04/integrated_production_pest_management_west_africa.pdf

Zambia

58. Michelo R., Kapete Ecological Centre. Green Revolution: Zambia's Trailblazing Bokashi Fertilizer Initiative Reshapes Agriculture. https://afsafrica.org/wp-content/uploads/2024/01/green-revolution-zambias-trailblazing-bokashi-fertilizer-initiative-reshapes-agriculture.pdf
59. Belmain S.R., Stevenson P.C.. Using Pesticidal Plants for Pest Management in Africa. https://afsafrica.org/wp-content/uploads/2019/04/using-pesticidal-plants-for-pest-management-in-africa.pdf

60. The Seed Knowledge Initiative Agroecology Landscape Barefoot Guide Writer's Collective. Juliet's Story: Strengthening farmers' seed systems. https://www.seedandknowledge.org/wp-content/uploads/2021/08/BFG-Landscape-Chapter-3-The-Lamenting-is-Over-lores.pdf

Sierra Leone

61. The Oakland Institute, Alliance for Food Sovereignty in Africa (AFSA). (n.d.). Organic Cocoa in Sierra Leone. https://afsafrica.org/wp-content/uploads/2019/04/organic_cocoa_sierra_leone.pdf

Appendix 2: Key Informant Interview Guide

1. Can you describe the specific agroecological practices your organization has implemented to enhance soil health, and what has been the most impactful practice in your experience?

2. What challenges have you encountered in promoting or implementing agroecological practices within your community or region, and how have you addressed them?

3. How do local government policies and regulations impact your ability to implement sustainable soil management practices, and what changes would you recommend?

4. In your experience, how has the adoption of agroecological practices impacted livelihoods in your community?

5. What role do traditional knowledge and local community involvement play in the success of your soil health initiatives?

6. Can you provide examples of how your organization has worked to improve access to markets for agroecologically produced goods, and what challenges persist in this area? What are the solutions?

7. How has climate change affected your soil management strategies, and what adaptive measures have you implemented in response?

8. What are the key indicators you use to monitor and evaluate soil ecosystem health, and how do these indicators inform your transition to agroecology?

Appendix 3: Interview transcripts

(Separate Document)

Appendix 4: Data Extraction Form

(Separate Document)