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Agroecological practices are associated with reduced food insecurity across continents over time

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Abstract
Achieving Sustainable Development Goal 2 (No Hunger) appears increasingly challenging at the global scale, with progress having stalled over the past decade. Nevertheless, emerging evidence from diverse local contexts suggests that agroecological farming practices may contribute substantially to reducing food insecurity. Here we draw on a dataset of more than 30,000 households from 17 countries measuring (a) the number and type of adopted agroecological farming practices and (b) household food insecurity, assessed using the Food Insecurity Experience Scale (FIES). Across most projects (22 out of 32), food insecurity declined over the four observed years (2021–2024). Adoption of practices from at least three agroecological groups was associated with 27% and 35% lower odds of moderate-or-severe and severe food insecurity, respectively. These findings add to a growing body of evidence supporting agroecological approaches, which have been associated with co-benefits such as biodiversity conservation, enhanced soil health, reduced greenhouse gas emissions, decreased agrochemical dependence, and improved human health outcomes, and could therefore inspire policies aiming to shape sustainable and equitable food systems.

Keywords Agroecology · Food insecurity · Smallholder farmers · Food insecurity experience scale · Sustainable food systems

Introduction

Progress on SDG 2 (Zero Hunger) has been lost since 2014, driven by a range of interconnected factors including poverty, inequality, armed conflict, declining agricultural productivity, and unsustainable resource use and management[1,2]. Food insecurity is not only a consequence of these dynamics but also a catalyst for further environmental degradation: food-insecure households often resort to coping strategies, such as expanding cultivation onto marginal land, shortening fallow periods, or overexploitation of soils and natural resources[3]. These factors drive soil degradation and biodiversity losses, and heighten vulnerability to climate change, which further erodes the basis for food production[4]. Socially, food insecurity undermines the foundations of healthy, self-determined lives, increases forced migration, and disrupts families and communities. Paradoxically, nearly half of those

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experiencing food insecurity are smallholder farmers, with women and also children disproportionately affected across all regions[1]. Approaches associated with the Green Revolution have largely failed to eradicate hunger, as they have tended to prioritise export-oriented cash crops over local food systems, often neglecting the food security of rural communities and not addressing related health outcomes[5,6]. Further, gains in yields and productivity were often made at the cost of essential associated ecosystem services critical for agricultural production, as shown for instance by widespread decline in insect populations over the last decades, hence suggesting that these productivity gains are not sustainable[7–9].

Agroecology has been gaining increasing recognition and popularity across a broad range of actors, including small-scale and large-scale farmers, non-governmental organisations (NGOs), governmental bodies, private sector stakeholders, and international development and cooperation agencies[10]. Recently, several international organisations have taken this movement up as shown by the FAO formulating a list of 10 elements of agroecology[11,12], or the 13 principles of agroecology by the High Level Panel of Experts on Food Security and Nutrition[10]. This growing interest reflects a widespread search for sustainable alternatives to industrial agriculture that can simultaneously address environmental, social, and economic challenges[13,14], fulfilling a range of regenerative functions[10].

A growing body of scientific evidence shows the potential of agroecology to reduce food insecurity and increase the resilience of small-scale farmers[15,16]. Diversified farming systems, in particular, have been shown to enhance food production and income at the household and community levels[17,18]. Meta-studies such as Bezner Kerr et al. (2021) indicate that adoption of agroecological practices is associated with positive food security and nutrition outcomes[17]. Further, several studies show that the adoption of multiple agroecological practices in conjunction (such as crop diversification, intercropping, agroforestry, and soil fertility management) can yield positive effects on food security and nutrition outcomes[19–22]. Diversified agroecosystems also deliver other co-benefits across environmental and social dimensions, contributing to biodiversity conservation, soil and water health, and climate resilience[16,23].

Most evidence on the link between agroecology and food security to date comes from local, often cross-sectional case studies. To address this gap, the aim of this study is to test whether agroecology's contribution to reducing food insecurity holds across a broad set of countries and over time. Specifically, we examine (i) the extent to which the number of agroecological practices adopted by a household is associated with higher food security, and (ii) whether adopting a greater number of agroecological practice groups is associated with lower food insecurity.

This study builds on data collected by the Sufosec Alliance (Swiss Alliance for Sustainable Food Systems and Empowered Communities), a consortium of six Swiss NGOs working to reduce hunger and poverty by strengthening local food systems through agroecology. Together with its local partners, the Sufosec Alliance promotes diversified agriculture and tests locally adapted cultivation methods while strengthening social networks and communities. The Sufosec Alliance and their partner organisations work with smallholder farming households and since 2021, Sufosec has collected data annually on agroecology adoption and food insecurity. In total, over 30,000 households at 44 project sites in 17 countries have been surveyed. While most of the existing evidence on the link between agroecology and food security emerges from individual case studies or single-country samples, the size, geographic breadth, and multi-year structure of this dataset are unprecedented. Using a standardised set of agroecological practice groups and a common food insecurity measure across all sites allows us to test whether the adoption of agroecology is associated with reduced food insecurity across a broad range of countries and over time.

Results

Evolution of number of agroecological practices at the project level

The average number of agroecological practices adopted per household rose from **5.0** in 2021 to 10.3 in 2023, before declining **to 9.2** in 2024 (Fig. 1b). Adoption trends varied considerably across individual projects (Fig. 1c; full annual adoption rates in Supplementary Table 5). The ten most commonly applied practices were: partial application of organic fertilizers (applied by 79.9% of households surveyed in 2024; 75.7% four-year average), production and use of locally adapted seeds (79.7% in 2024; 71% overall), intercropping (78.3% in 2024; 68% overall), crop rotation (72.4% in 2024; 72.5% overall), diversification of crops (70.8% in 2024; 66.2% overall), application of organic fertilizers (66.4% / 59.5%), integration of livestock and crop production (64% / 51.9%), agroforestry (52.4% / 47.0%), exclusive use of organic fertilizers (49.7% / 42.0%), and mulching (45.4% / 44.2%). Regarding agroecological practices, 28 project sites show an increase in the number of practices implemented, while only four sites show a decrease (Fig. 3d).

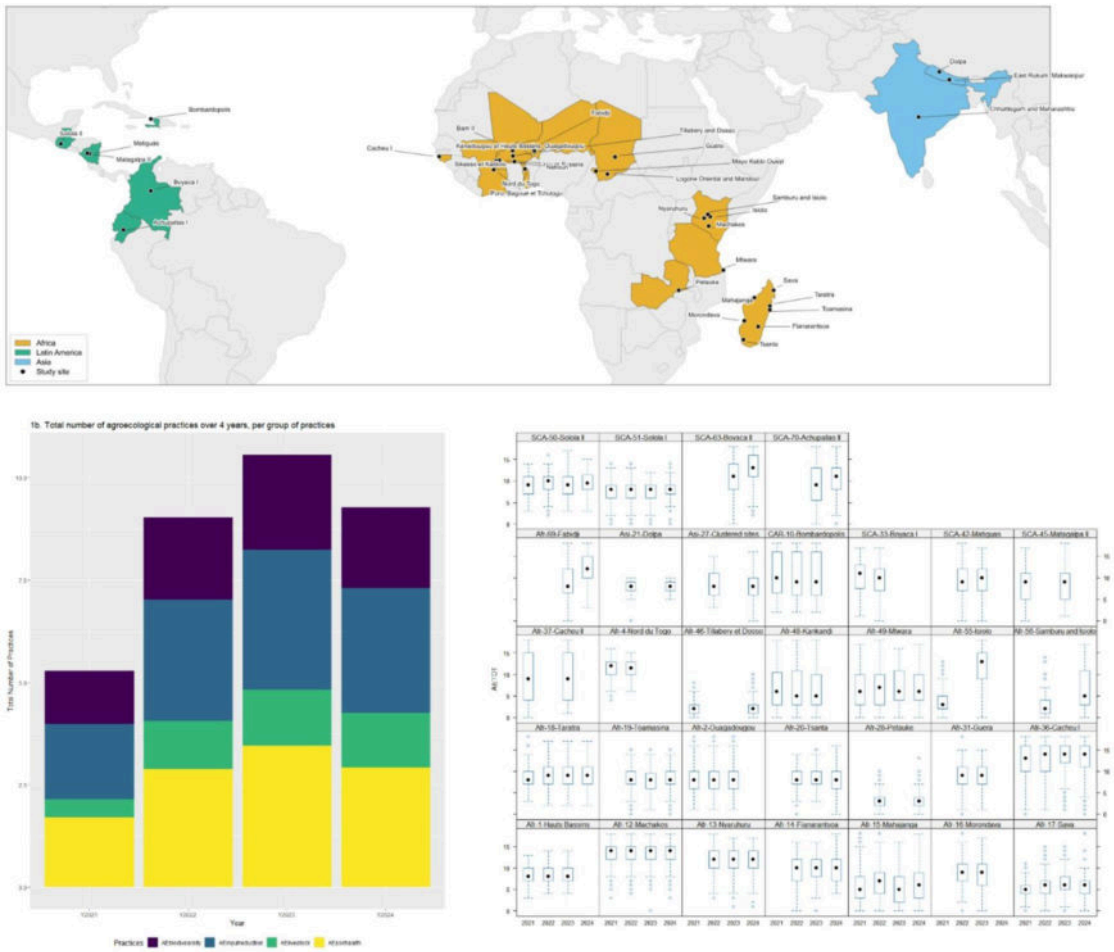

Fig. 1 (**a**) Geographical coverage of projects included in this study (**b**) average number of agroecological practices adopted per household (2021–2024) across projects and four groups of practices. (**c**) Adoption trends by individual project, showing considerable between-project variance.

Association between food insecurity and the number of agroecological practices adopted

Figure 2 illustrates the evolution of moderate-or-severe and severe food insecurity across the surveyed projects. Overall, both forms of food insecurity show a declining trend, suggesting an improvement in food access among the studied populations. However, the trajectories are not entirely linear, with some fluctuations visible across individual projects. This suggests that the reduction in food insecurity has been uneven and context dependent.

Food insecurity levels were calculated using the FIES raw scores[24]. Moderate-or-severe food insecurity affected 65% of surveyed households in 2021, 69% in 2022, 56% in 2023, and 57% in 2024 (Fig. 2). Both moderate-or-severe and severe food insecurity declined overall, although trajectories were not linear and varied across project sites. Between the first and last year of available data, 22 project sites recorded a decrease in both moderate-or-severe and severe food insecurity, while 10 recorded an increase (Fig. 3c).

Results of the mixed-effects models are presented in Table 1 for projects with at least two years of survey data and projects with at least three years of data. Household size was associated with higher odds of food insecurity (OR > 1 in all models). The number of years as a project beneficiary was associated with lower odds of experiencing moderate-or-severe or severe food insecurity. Respondent gender was not significantly associated with either outcome. This may be because the variable captures only the gender of the respondent and not the structure of the household, for example, whether it is single-headed, which is likely more relevant to food insecurity than respondent gender alone.

To test the statistical association between the total number of agroecological practices and the prevalence of food insecurity per household, we built a mixed-effects model. This model assesses the adoption of multiple agroecological practices and includes the following predictors: year of survey, household size, number of years as beneficiaries (beneficiary-since), and the number of agroecological practices adopted. The outcome variables

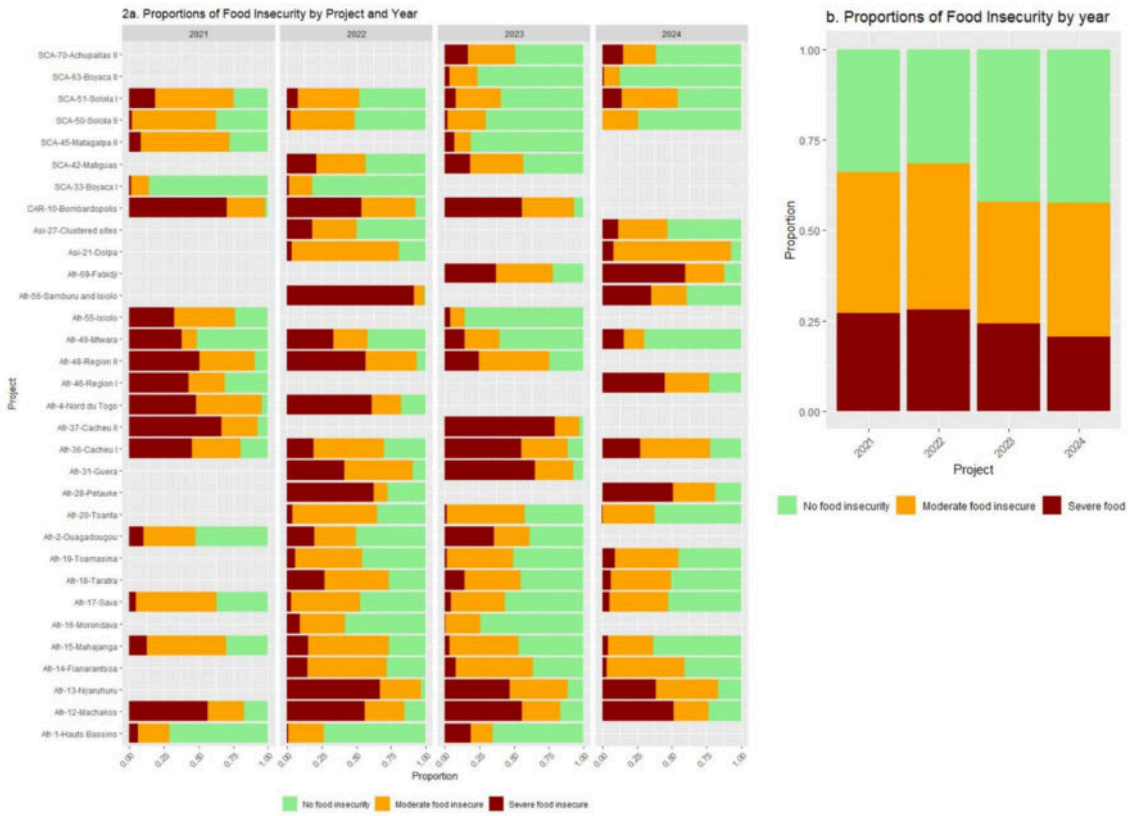

Fig. 2 Evolution of food (in)security over the four years in the monitored projects.

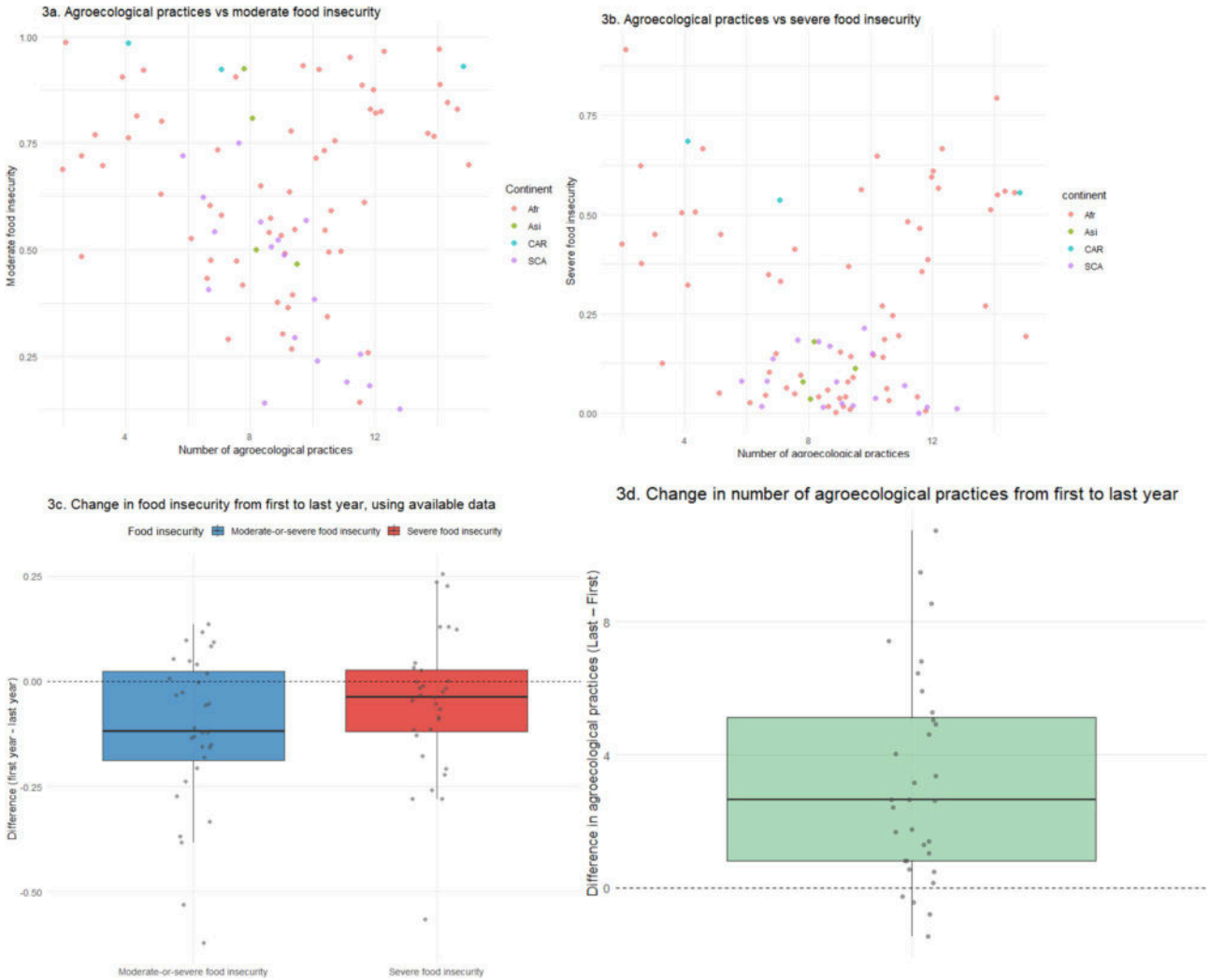

Fig. 3 Relationship between food insecurity and number of agroecological practices and evolution of both between baseline and endline.

are moderate-or-severe food insecurity and severe food insecurity. We applied the model to two sub-samples: first, projects with at least two years of survey data (left panel), and second, projects with at least three years of data (right panel).

Figure 3a and b illustrate the association between the total number of agroecological practices implemented by respondents and the prevalence of moderate-or-severe and severe food insecurity. Overall, both forms of food insecurity decline as households adopt a greater number of practices, indicating a positive relationship between agroecological implementation and improved food security outcomes. Figure 3c and d depict changes over time in both indicators— moderate-or-severe and severe food insecurity (Fig. 3c) and the total number of agroecological practices adopted (Fig. 3d). Each point represents a project site, showing the difference in values between the first and last available observations for that project. Because not all projects have data for all four years, the number of years spanned by this comparison varies across sites.

Each additional agroecological practice adopted was associated with lower odds of moderate-or-severe food insecurity in the sample of projects with at least two years of data (OR = 0.97, 95% CI = 0.97–0.98, $p < 0.001$), but this association was not statistically significant in the sample restricted to projects with at least three years of data (OR = 1.00, 95% CI = 0.99–1.01, $p = 0.890$). For severe food insecurity, each additional agroecological practice

Table 1 Generalised mixed-model testing the association between moderate-or-severe and severe food insecurity and several independent variables.

Predictors	moderatebi			severebi			moderatebi			severebi		
	Odds Ratios	CI	*p*	Odds Ratios	CI	*p*	Odds Ratios	CI	*p*	Odds Ratios	CI	*p*
(a)												
(Intercept)	4.27	2.70–6.75	**<0.001**	0.37	0.21–0.66	**0.001**	2.61	1.56–4.38	**<0.001**	0.24	0.12–0.48	**<0.001**
gender	1.06	0.99–1.14	0.087	1.07	0.98–1.17	0.129	1.07	0.98–1.16	0.116	1.08	0.97–1.20	0.160
year2	0.72	0.70–0.75	**<0.001**	0.82	0.79–0.86	**<0.001**	0.79	0.76–0.82	**<0.001**	0.89	0.85–0.94	**<0.001**
hhsize2	1.05	1.03–1.06	**<0.001**	1.03	1.02–1.04	**<0.001**	1.05	1.04–1.06	**<0.001**	1.04	1.02–1.05	**<0.001**
beneficiary since2	0.97	0.95–0.98	**<0.001**	0.95	0.93–0.97	**<0.001**	0.97	0.95–0.99	**0.001**	0.94	0.92–0.96	**<0.001**
AETOT2	0.97	0.97–0.98	**<0.001**	0.99	0.98–1.00	**0.009**	1.00	0.99–1.01	0.890	0.99	0.97–1.00	**0.034**
Random Effects												
σ^2	3.29			3.29			3.29			3.29		
τ_{00}	1.43 projectID			2.19 projectID			1.00 projectID			1.87 projectID		
ICC	0.30			0.40			0.23			0.36		
N	29 projectID			29 projectID			16 projectID			16 projectID		
Observations	23,473			23,473			16,659			16,659		
Marginal R^2 / Conditional R^2	0.041 / 0.331			0.016 / 0.409			0.027 / 0.254			0.013 / 0.371		

Predictors	moderatebi			severebi			moderatebi			severebi		
	Odds Ratios	CI	*p*	Odds Ratios	CI	*p*	Odds Ratios	CI	*p*	Odds Ratios	CI	*p*
(b)												
(Intercept)	4.08	2.58 – 6.45	**<0.001**	0.36	0.21 – 0.63	**<0.001**	2.75	1.64 – 4.63	**<0.001**	0.24	0.12 – 0.47	**<0.001**
gender	1.07	0.99 – 1.15	0.070	1.07	0.98 – 1.17	0.122	1.07	0.99 – 1.16	0.106	1.09	0.97 – 1.21	0.139
year2	0.72	0.70 – 0.75	**<0.001**	0.81	0.78 – 0.85	**<0.001**	0.80	0.77 – 0.83	**<0.001**	0.90	0.85 – 0.94	**<0.001**
hhsize2	1.04	1.03 – 1.06	**<0.001**	1.03	1.02 – 1.04	**<0.001**	1.05	1.04 – 1.07	**<0.001**	1.04	1.02 – 1.05	**<0.001**
beneficiary since2	0.97	0.95 – 0.99	**<0.001**	0.95	0.93 – 0.97	**<0.001**	0.97	0.95 – 0.99	**0.001**	0.94	0.92 – 0.97	**<0.001**
AETOT3	0.98	0.97 – 0.98	**<0.001**	0.99	0.98 – 1.00	0.063	0.99	0.98 – 1.00	**0.046**	0.98	0.97 – 0.99	**0.004**
Random Effects												
σ^2	3.29			3.29			3.29			3.29		
τ_{00}	$1.44^{projectID}$			$2.19^{projectID}$			$1.02^{projectID}$			$1.87^{projectID}$		
ICC	0.30			0.40			0.24			0.36		
N	$29^{projectID}$			$29^{projectID}$			$16^{projectID}$			$16^{projectID}$		
Observations	23,466			23,466			16,652			16,652		
Marginal R^2 / Conditional R^2	0.041 / 0.332			0.016 / 0.409			0.027 / 0.257			0.013 / 0.371		

Table a on top shows a statistical association between the number of practices adopted and food insecurity. Table b shows a similar model but removing agroecological practices that were only adopted in the last 12 months before the survey. This only marginally increases the effect size.

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adopted was also associated with lower odds in both samples, with odds ratios of 0.99 (95% CI = 0.98–1.00, $p = 0.009$) in the sample of projects with at least two years of data and 0.99 (95% CI = 0.97–1.00, $p = 0.034$) in the sample restricted to projects with at least three years of data. While the effect size is relatively small—representing a 1% to 3% reduction in odds—the effect is cumulative for each agroecological practice adopted by the household. This means that households adopting a wide range of agroecological practices may experience substantially lower odds of food insecurity over time, even if the contribution of each single practice is modest. Excluding newly adopted practices has only a marginal impact on the model but slightly increases the overall effect size (Table 1b). To aid interpretation, we also computed the average marginal effects, which express each additional practice as a change in the predicted probability of food insecurity rather than in odds (Supplementary Table 6). The association was strongest for moderate-or-severe food insecurity in the two-year dataset, where estimates indicate that the adoption of 10 practices is associated with an approximate 10-percentage-point lower predicted probability for moderate-or-severe food insecurity (AME = -0.1049, 95% CI = -0.1301 to -0.0891, $p < 0.001$).

Association between food insecurity and complex agroecological systems

To test the hypothesis that more complex agroecological systems are associated with lower risks of food insecurity, we built the models presented in Table 2; Fig. 4. The variable AE3groups designates households that have adopted at least one practice from three agroecological subgroups, while AE4groups applies to those adopting at least one practice from all four groups. For households classified under AE3groups, the odds ratios for being moderately-or-severely and severely food insecure are 0.73 (95% CI = 0.66–0.81) and 0.65 (95% CI = 0.58–0.72), respectively. Among households in the AE4groups category, the number of practices adopted is not associated with moderate-or-severe food insecurity (OR of 0.96, 95% CI = 0.89–1.02) but is associated with lower odds of severe food insecurity, with an odds ratio of 0.84 (95% CI = 0.77–0.91).

Despite the lack of association with moderate-or-severe food insecurity in the four-group category, these findings support our initial hypothesis that more diversified agroecological systems are generally associated with a lower likelihood of food insecurity. Figure 4 presents the results from the latter model and summarises the effect sizes across all models.

Discussion

Our analysis indicates that agroecological practice adoption is associated with lower food insecurity across diverse social-ecological contexts. Specifically, each additional practice adopted is associated with a 1–3% reduction in the odds of moderate-or-severe or severe food insecurity. As agroecology places food security and nutrition at the core of its approach and conceptual framework, agroecological interventions are widely regarded as having the potential to address multiple dimensions of food security while simultaneously enhancing resilience of small-scale farmers. In a review of conceptual frameworks, Dagunga et al. (2023) found that only one out of 47 articles did not explicitly link agroecology to local food security[16]. Positive outcomes of agroecological production have been reported in case studies from various regions. For example, Bezner Kerr et al. (2021) compiled empirical findings demonstrating strong links between agroecology and improved food security[17]. These associations are particularly evident during times of crisis, such as economic hardship, as seen in the development of agroecology in Cuba, ecological catastrophes, such as hurricanes[25], or cumulative hazards such as crop failure and adverse climatic conditions[26].

Further, production systems that combine multiple agroecological practices were generally associated with lower odds of food insecurity, except in one model where the effect was not statistically significant. This result is largely consistent with existing research. Several studies suggest that crop diversification or agroforestry can yield long-term benefits for food and nutrition outcomes by enhancing year-round food availability and improving

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Table 2 Generalised mixed-model testing the association between moderate-or-severe and severe food insecurity and complex agroecological systems.

Predictors	moderatebi			severebi			moderatebi			severebi		
	Odds Ratios	CI	*p*	Odds Ratios	CI	*p*	Odds Ratios	CI	*p*	Odds Ratios	CI	*p*
(Intercept)	4.63	2.94 – 7.31	**<0.001**	0.47	0.27 – 0.82	**0.008**	3.76	2.39 – 5.92	**<0.001**	0.36	0.21 – 0.63	**<0.001**
gender	1.06	0.99 – 1.14	0.102	1.06	0.97 – 1.16	0.171	1.06	0.99 – 1.14	0.086	1.07	0.98 – 1.16	0.144
year2	0.71	0.69 – 0.73	**<0.001**	0.83	0.80 – 0.87	**<0.001**	0.70	0.68 – 0.73	**<0.001**	0.82	0.79 – 0.86	**<0.001**
hhsize2	1.04	1.03 – 1.06	**<0.001**	1.03	1.02 – 1.04	**<0.001**	1.04	1.03 – 1.06	**<0.001**	1.03	1.02 – 1.04	**<0.001**
beneficiary since2	0.96	0.95 – 0.98	**<0.001**	0.95	0.93 – 0.97	**<0.001**	0.96	0.95 – 0.98	**<0.001**	0.95	0.93 – 0.97	**<0.001**
AE3groups	0.73	0.66 – 0.81	**<0.001**	0.65	0.58 – 0.72	**<0.001**						
AE4groups							0.96	0.89 – 1.02	0.193	0.84	0.77 – 0.91	**<0.001**
Random Effects												
σ^2	3.29			3.29			3.29			3.29		
τ_{00}	$1.40_{projectID}$			$2.14_{projectID}$			$1.42_{projectID}$			$2.20_{projectID}$		
ICC	0.30			0.39			0.30			0.40		
N	$29_{projectID}$			$29_{projectID}$			$29_{projectID}$			$29_{projectID}$		
Observations	23,473			23,473			23,473			23,473		
Marginal R^2 / Conditional R^2	0.042 / 0.328			0.019 / 0.405			0.039 / 0.329			0.016 / 0.411		

Households that have implemented agroecological practices from at least 3 groups (AE3 groups) are less likely to be associated with moderate-or-severe and severe food insecurity. For practices from 4 groups (AE4groups), this association is only significant for severe food insecurity.

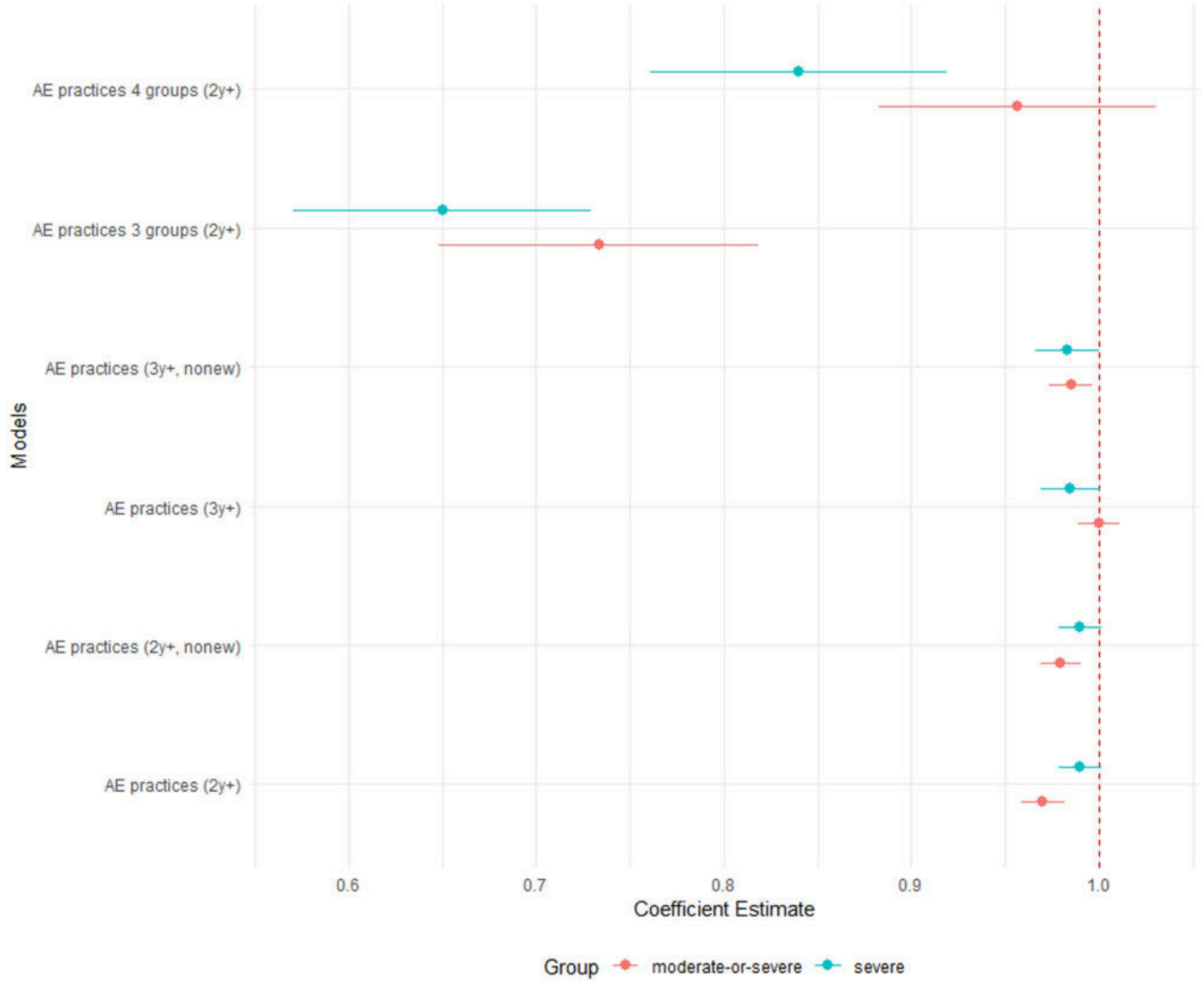

Fig. 4 Overview of all coefficients of the models tested. Overall, most of the models show that adoption of agroecological practices is associated with lower food insecurity. In particular, complex agroecological systems are associated with significantly lower odds of moderate-or-severe and severe food insecurity.

the variety of food[19–21]. Improvements in nutrition and food security can be significant when agricultural interventions are paired with practices supporting livestock[17,27]. The available literature also indicates that adoption of agroecological practices can result in productivity gains which, when combined with lower input costs, can enhance food security, particularly among smallholder farmers in the Global South[28]. Furthermore, enhancing resilience to natural disasters and climate change is a central objective of agroecological interventions[23,29,30]. Strengthening this resilience is crucial to help communities cope with immediate shocks, but it can also lead to long-term improvements in the food security of vulnerable populations[16,31].

Although this study focuses specifically on food insecurity and the adoption of agroecological practices in the sense of regenerative agriculture, several of the projects also integrated social interventions, such as gender empowerment. Recent studies have emphasised that interventions focusing on social dimensions, combined with specific agricultural interventions, can yield significant positive outcomes. Hence, previous research showed that improvements in nutrition and women's empowerment are often the result of agroecological interventions[32,33]. One of the greatest potentials of agroecology as a transformative science lies in its capacity to integrate on-farm practices with social innovations. However, further research is needed to explore how the synergy between social

and traditional agricultural interventions can be optimised to enhance both social and environmental outcomes[34]. Moreover, there remains a significant gap in research and indicator reporting on social aspects, including employment opportunities, working conditions, and different dimensions of gender equality[35,36].

In line with Bezner Kerr et al. (2021), we conclude that the positive association of agroecological practices with food security and nutrition is even more substantial when considering additional benefits documented in the literature, including contributions to biodiversity and soil conservation, pesticide reduction, climate change adaptation and mitigation, social-ecological resilience, contributive justice, and local development. Within the global agroecological movement, such practices are often regarded as a basis or condition for food sovereignty due to their emphasis on local inputs and knowledge, among others. In contrast to other approaches that have been developed by international organisations in the past, agroecology is characterised by a clear transformative intent and is rooted in the paradigm of food sovereignty[15,37].

Our results also indicate that in regions characterised by high political insecurity and vulnerability to climate change impacts, the adoption of agroecological practices remains limited. Many of the surveyed households and projects are situated in areas prone to repeated socio-environmental crises. Contextual factors, such as climate impacts or political instability, significantly influence the adoption and feasibility of implementing agroecological practices. For instance, in the study site in Isiolo County, Kenya, severe droughts between 2017 and 2022 exacerbated conflicts over land and water. However, improved precipitation in 2023 led to an overall decrease in food insecurity, from 73% in 2021 to 16% in 2023 within our sample. In contrast, the study site in Guèra, Chad, faced a difficult political situation following the death of long-time President Idriss Déby in 2021. This political transition, along with ongoing conflicts between smallholder farmers and pastoralists, exacerbated the impacts of climate change and contributed to an increase in food insecurity—from 74% in 2021 to 92% in 2023 in our sample. Long-term agroecological strategies must therefore be combined with humanitarian aid[38].

Conclusion

Our findings indicate that across diverse contexts, the adoption of agroecological practices — particularly integrated systems spanning multiple domains — is associated with lower odds of food insecurity. We conclude from these varying experiences that while agroecological practices are essential, they are not sufficient to withstand or counteract such contextual factors. Sustainable development cooperation, along with humanitarian aid, is also an indispensable pillar of food security, especially in fragile contexts. Responsible private sector actors, as well as governmental and non-governmental organisations, are positioned to create, support, and strengthen the conditions necessary for the implementation of agroecological practices, and adoption of policies supporting agroecology[39]. Enabling capability development and the empowerment of local actors are crucial ingredients to sustainably and permanently reduce food insecurity.

These results carry clear policy implications. First, despite decades of investment in agricultural intensification, global progress towards Zero Hunger (SDG 2) has stalled. Policies aiming to achieve SDG 2 should therefore complement productivity-oriented agricultural strategies with stronger support for agroecological food systems. Our findings add to a growing body of evidence showing that agroecological practices can significantly contribute to food security across diverse contexts. Rather than treating agroecology as a niche approach, governments and development agencies should recognise it as a key pathway for building resilient, sustainable and equitable food systems.

Second, agricultural policies should promote integrated agroecological systems rather than isolated technical interventions. Households adopting practices from multiple agroecological domains showed substantially lower odds of food insecurity than those adopting fewer or less diversified practices, suggesting that integrated agroecological systems deserve greater policy support than single technologies or practices.

Third, scaling agroecological transitions requires long-term public investment and enabling policy environments. The gradual increase in agroecological practice adoption and the concurrent decline in food insecurity

observed across projects suggest that agroecological transitions are cumulative processes. Stable extension services, locally adapted innovation and long-term support for smallholder farmers are therefore more likely to generate sustained improvements than short-term technology-transfer projects.

Policy implications

It is important to complement productivity-oriented strategies with agroecology: Policies targeting SDG 2 should move beyond agricultural intensification and give agroecological food systems a central role as a pathway to resilient, sustainable, and equitable food security.

Policies should support integrated systems, not isolated practices. Because households combining practices across multiple agroecological domains showed the greatest reductions in food insecurity, funding and extension should reward whole-system transitions rather than single technologies.

Investments should be for the long term. Agroecological transitions are cumulative; stable extension services, locally adapted innovation, and sustained support for smallholders will outperform short-term technology-transfer projects.

Limitations

Several limitations should be considered when interpreting our results. First, our study builds on a repeated cross-sectional survey rather than a panel: because households were not tracked across years, we observe trends at the project level but cannot follow individual households over time. Second, the survey collected only a limited set of controls: household size, respondent gender, and years in the project. Unobserved factors such as wealth, land endowment or education, and diverse external factors may influence both practice adoption and food security. The associations we report should therefore not be interpreted as causal. The absence of a control group prevents us from establishing what food insecurity would have been without the interventions in the project areas.

Methods

Description of the intervention and data collection

The Sufosec Household Survey 2021–2024 was introduced as part of the Sufosec joint monitoring system. The survey includes two sections: (a) the Food Insecurity Experience Scale (FIES) questionnaire of the FAO and (b) questions on 18 agroecological practices applied by the household. These practices are grouped into four thematic categories: biodiversity, soil health, input reduction, and synergies with livestock. Table 3 presents the associations between groups and practices.

Study design

The survey follows a repeated cross-sectional design. In each study site, a representative sample is drawn annually using random sampling, with sample sizes calculated to achieve a 95% confidence level and a 5% margin of error. Data are collected digitally using KoboCollect on the KoboToolbox platform via mobile devices, following survey protocols developed and approved by the Sufosec core group, which includes members from each partner organisation. The primary respondent was an adult woman in the household knowledgeable about both its food security situation and farming practices; where no eligible woman was available, an adult man was interviewed instead.

Table 3 Overview of Sufosec list of agroecological practices implemented at the project level.

AE farming practice	AE group
Agroforestry	Biodiversity
Barriers and terraces	Soil health
Controlled grazing	Synergy with livestock
Crop diversification	Biodiversity
Crop rotation	Biodiversity
Efficient and water-saving irrigation/water management	Input reduction
Exclusive application of organic fertilizer	Soil health
Exclusive application of organic pesticide	Input reduction
Integration of livestock with crop production	Synergy with livestock
Intercropping	Soil health
Mulching	Soil health
Other water and soil conservation methods	Soil health
Partial application of organic fertilizer	Input reduction
Partial application of organic pesticide	Input reduction
Production/use of locally adapted seed	Input reduction
Rehabilitation of degraded grazing land	Synergy with livestock
Sustainable rangeland management	Synergy with livestock
Windbreaks and living fences	Soil health

These 18 practices are divided into four groups, corresponding to major intervention fields of agroecology. These practices are also consistent with key principles of regenerative agriculture[42].

To capture contextual conditions, Sufosec also administers an annual project-site questionnaire covering project intervention, target population, geographic setting, and relevant socio-political and environmental dynamics, including the occurrence of conflict, displacement, civil unrest, and climatic shocks such as natural disasters or extreme weather events.

Sample and project selection

Each alliance member organisation independently selected the projects in which to implement the survey indicators. The survey was conducted in 63 projects across 19 countries, reaching more than 46,000 households over the four-year period. 19 projects were excluded due to methodological inconsistencies or incomplete datasets. The final analytical sample comprises 44 projects in 17 countries, with each project contributing a methodologically consistent dataset containing complete information on both agroecological practices and FIES indicators for at least one survey year (see Table 4). The projects that were excluded were either missing the Agroecology or food insecurity module of the questionnaire. This final dataset includes data from over 30,000 households.

Ethics

In each country, Sufosec partner organisations are authorised by the relevant national authorities to collect monitoring and evaluation data from beneficiaries for the purpose of assessing and improving intervention delivery. As the data were gathered under this mandate as part of routine programme monitoring — involving anonymous, non-clinical household surveys that posed minimal risk and collected no personally identifying information — no central ethics committee approval was required for this research. Informed consent was obtained from all participants prior to data collection; participation was voluntary and anonymous, and respondents could decline or withdraw at any time.

Calculation of FIES

The FIES was calculated at the household level by first calculating the raw score and running the Rasch model from FAO to check for validity of each response item and robustness of data at the project level. In order to assess the validity of each response item, we used the INFIT statistics, as recommended by FAO statistics [24]. The

Table 4 Overview of Sufosec Household Survey projects included in the analysis (2021–2024).

Project ID	Country (Region)	2021	2022	2023	2024
1	Burkina Faso (Hauts Bassins)	406	203	134	
2	Burkina Faso (Ouagadougou)	599	389	214	
4	Togo (Nord du Togo)	189	200		
5	Burkina Faso (Bam II)	164			
6	Burkina Faso (Bam I)	155			
7	Burkina Faso (Nahouri)	310			
10	Haiti (Bombardopolis)	217	222	232	
12	Kenya (Machakos)	364	332	372	390
13	Kenya (Nyaruhuru)		346	367	383
14	Madagascar (Fianarantsoa)		394	385	388
15	Madagascar (Mahajanga)	701	389	378	391
16	Madagascar (Morondava)		293	213	
17	Madagascar (Sava)	796	406	394	389
18	Madagascar (Taratra)	97	362	390	323
19	Madagascar (Toamasina)		413	415	416
20	Madagascar (Tsanta)		389	386	378
21	Nepal (Dolpa)		366		319
27	Nepal (clustered sites)		417		443
28	Zambia (Petauke)		183		134
29	Chad (Logone Oriental and Mandoul)	398			
30	Chad (Mayo Kebbi Ouest)	406			
31	Chad (Guéra)		407	393	
33	Colombia (Boyacá I)	136	139		
35	Ecuador (Achupallas I)		289		
36	Guinea Bissau (Cacheu I)	332	674	354	353
37	Guinea Bissau (Cacheu II)	336		336	
42	Nicaragua (Matiguás)		206	203	
45	Nicaragua (Matagalpa II)	211		177	
46	Niger (Région I)	699			546
48	Niger (Région II)	224	150	102	
49	Tanzania (Mtwara)	392	317	274	
50	Guatemala (Sololá II)	72	75	74	72
51	Guatemala (Sololá I)	153	153	149	153
52	Burkina Faso (Kénédougou et Hauts Bassins)	59			
53	Côte d'Ivoire (Poro, Bagoué et Tchologo)	199			
55	Kenya (Isiolo)	582		695	
56	Kenya (Samburu and Isiolo)		478		455
58	Mali (Sikasso et Kadiolo)	180			
60	India (Chhattisgarh and Maharashtra)			358	
63	Colombia (Boyaca II)			170	179
68	Guatemala (Sololá III)				148
69	Niger (Fabidji)			276	242
70	Ecuador (Achupallas II)			223	256

undefinedList of 44 projects with corresponding project IDs, countries and regions, and the number of surveyed households per year. Only projects with methodologically complete data on both agroecological practices and food security (FIES) for at least one year are included. List of projects not included in the analysis included in Table 7 (supplementary material).

raw score was used to construct two binary indicators of food insecurity: moderate-or-severe food insecurity and severe food insecurity. Households with a raw FIES score of 4 or more were classified as moderately-or-severely food insecure, while households with a raw score of 7 or more were classified as severely food insecure; because the second threshold is nested within the first, all severely food insecure households are also captured within the moderate-or-severe food insecurity indicator [24]. This method is consistent with the recommendations from FAO [24], and other research using the FIES [40].

Direct comparison of Sufosec FIES prevalence with national-level reference is conducted but should be interpreted with caution due to different methodological and demographic factors [1, 38]. The Sufosec programmes

primarily target highly vulnerable populations, which are not representative of national averages. Furthermore, Sufosec data are reported on an annual basis, whereas FAO national FIES estimates are presented as three-year rolling averages [1].

Modelling and data analysis

To test the association between the number of agroecological practices adopted and household food insecurity, we estimated a series of mixed-effects logistic regression models. A mixed-effects model incorporates both fixed effects (population-wide parameters like age or gender) and random effects (variability specific to clusters) [41]. In the mixed-effects models presented in this paper, most independent variables, such as respondent gender, household size, years, and agroecological practices, are treated as fixed effects. Project sites, on the other hand, are treated as random effects.

For all our models, the outcome variables were moderate-or-severe and severe food insecurity [24]. We applied each model to two sub-samples: first, all projects with at least two years of survey data, and second, projects with three or more years of survey data. A complete data description, including data on each FIES dimension can be found in Table 5 (supplementary material).

Including the number of years as a project beneficiary as a control was intended to partly account for the absence of a longitudinal design. To control for any potential post-treatment bias, our models were also estimated without this variable. Results for these complementary analyses are presented in Table 8 (supplementary material).

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Data availability The data supporting this paper is available in the data repository Zenodo, with the following DOI: 10.5281/zenodo.15675175. The data presented is simplified. R scripts and further material can be made available upon request to the corresponding author.

Declarations

Competing interests The authors declare no competing interests.

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