Agroecology TPP

Kenya country report on Measuring Agroecology and its Performance (MAP)

TAPE application in the context of the GIZ global project Soil Protection and Rehabilitation for Food Security (ProSoil)

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The Transformative Partnership Platform on Agroecology (Agroecology TPP)

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Abbreviations and acronyms

Agroecology TPP	Transformative Partnership Platform on Agroecology
BMZ	Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung (German Federal Ministry for Economic Cooperation and Development)
CAET	Characterization of Agroecological Transition
CFS	Committee on World Food Security
CIFOR -ICRAF	Center for International Forestry Research - World Agroforestry
CIRAD	Centre de coopération internationale en recherche agronomique pour le développement (French Agricultural Research Centre for International Development)
DeSIRA	Development Smart Innovation through Research in Agriculture initiative of the EU
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (German development agency)
ICRAF	International Council for Research in Agroforestry (World Agroforestry)
ISFAA	Intersectoral Forum on Agrobiodiversity and Agroecology
KNBS	Kenya National Bureau of Statistics
LDSF	Land Degradation Surveillance Framework
MAP	Measuring Agroecology and its Performance
MCT	Mercury cadmium telluride
ProSilience	DeSIRA project Enhancing Soils and Agroecology for Resilient Agri-food Systems in Sub-Saharan Africa implemented by GIZ and embedded in ProSoil
ProSoil	GIZ global project Soil Protection and Rehabilitation for Food Security
Stats4SD	Statistics for Sustainable Development
TAPE	Tool for Agroecology Performance Evaluation

Executive summary

As agroecology is increasingly viewed as a promising approach to render agricultural and food systems more sustainable, there is growing interest in assessing both the level of agroecological integration and the contribution of agroecology to achieving societal goals. To address both points of interest, the FAO's Tool for Agroecology Performance Evaluation (TAPE) was applied in the context of the GIZ global project Soil Protection and Rehabilitation for Food Security (ProSoil) in three Kenyan counties (Bungoma, Kakamega and Siaya). Since 2015, ProSoil has been building community capacity to implement agroecological farming practices. The application of TAPE aimed at assessing the degree to which ProSoil's interventions contributed to agroecological transitions among beneficiary households, and how the degree of agroecological integration correlates with multidimensional performance. TAPE results from 101 farms that have actively participated in ProSoil activities were compared with 100 farms that had not actively participated in ProSoil activities, serving as a comparison group. These comparison farms were selected from households targeted for the DeSIRA project Enhancing Soils and Agroecology for Resilient Agri-food Systems in Sub-Saharan Africa (ProSilience), which is embedded within ProSoil, but earmarked for implementation where ProSoil interventions have not been implemented.

As ProSoil has a specific emphasis on soil health, the Measuring Agroecology and its Performance (MAP) project amended the standard TAPE methodology by integrating robust soil sampling and analytics using the Land Degradation Surveillance Framework (LDSF) methodology to more specifically assess the contribution of agroecology to improved soil health within farms where ProSoil activities are implemented, as opposed to the comparison farms. Additionally, the MAP project, through Stats4SD, developed and utilized a novel data management platform for TAPE applications and analyses, streamlining overall field data entry and management processes. A total of 46 relevant food system actors – including representatives from government, private and non-governmental organizations, civil society, and farmers – participated in a collaborative interpretation of the observed results. Their involvement was crucial in providing context to the findings; identifying gaps; and proposing key recommendations to advance the agroecological transition.

Key findings of this report indicate that household participation in ProSoil interventions resulted in a significantly higher level of agroecological integration (CAET = 67%) compared with the comparison group (CAET = 38%), and consistently across the three counties. ProSoil group scored highly in all the elements of agroecology, with the lowest score recorded for responsible governance (CAET=58%). Likewise, there was a strong positive correlation among all elements of agroecology, implying a synergistic relationship among elements of agroecology. This underscores the notion that sustainability transcends specific farm practices and necessitates a broader scope to attain a more balanced and holistic system.

Regarding the performance of agroecology, there was a significant positive correlation between CAET score (which describes the integration of the 10 elements of agroecology) and multidimensional societal goals. An increased integration of agroecological practices was associated with several economic benefits, such as enhanced income ($r=0.64$, $p<0.001$) and wealth creation (added value) ($r=0.26$, $p<0.01$), improved productivity per hectare (ha) ($r=0.2$, $p<0.05$) and per person ($r=0.2$, $p<0.01$). While this presents agroecological advancement as a profitable venture, a temporary decline in productivity per hectare was noted during the initial stages of transitioning. Additionally, there was an observed increase in expenses for farm inputs, such as seeds, fertilizers, pesticides and machinery ($r=0.14$, $p<0.05$) as the CAET score increased. Nevertheless, participation in ProSoil activities is more likely to lower the expenses for farm inputs compared with the comparison group.

On social dimensions, agroecological transitions not only fostered women's empowerment ($r=0.2$, $p<0.05$) to engage in agriculture but also improved the overall diet score ($r=0.47$, $p<0.001$). This indicates that households with advanced integration of agroecological practices tend to have more diversified diets, lower food expenditures, and improved food security. However, there was no significant association ($r=-0.03$, $p>0.5$) between the CAET score and the overall youth score (youth employment and retention in agriculture). It appears that youth prefer less labour-intensive economic activities that have quick and guaranteed financial benefits, a condition rarely met by agroecology. The positive correlation between the CAET and the proportion of children ($r=0.2$, $p<0.01$) involved in agriculture was attributed to the interest developed among children in implementing innovative agroecological practices, as promoted in their school curriculum, which aims to produce self-reliant and innovative youths.

With regard to environmental indicators, TAPE analysis indicated that the CAET score positively correlates with overall soil health ($r=0.5$, $p<0.001$) and agrobiodiversity indices, focusing on the Gini-Simpson Index for crops ($r=0.39$, $p<0.001$), animals ($r=0.3$, $p<0.001$) as well as natural vegetation and pollinators ($r=0.5$, $p<0.001$). However, LDSF results indicate that the CAET score is not associated with the physiochemical characteristics of soil health (soil organic carbon, total nitrogen, pH, and phosphorus). Differences in these indicators were more associated with territorial factors, taking into account the different counties, rather than the implementation of agroecological farm practices.

Based on the findings, the study concludes that the implementation of programmes that support sustainable farming practices – like ProSoil – plays a key role in the holistic integration of agroecological practices, contributing to more sustainable farming systems. However, efforts to promote producer empowerment in decision making and natural resource governance are encouraged to further propel agroecological transitions. Considering the synergistic relationship among elements of agroecology, the integration of all elements in production systems is likely to advance agroecological transitions. Yet this may not be practical as implementers often set their own priorities that attempt to address key societal challenges. Thus, a collaborative effort from actors working on different, but related, aspects of agroecology would benefit holistic agroecological integration.

An increase in the level of agroecological integration yields positive economic, environmental and social outcomes. However, addressing young people's interest in agriculture is key to re-engaging them in farming practices. With this in mind, it is essential to integrate technology to reduce labour burdens; promote more informed marketing of produce; develop institutional instruments that support tenure security among youth; and align long-term sustainability goals with short-term economic benefits. Further, a disparity in soil results associated with the two methodologies employed implies that agroecological integration improves biophysical characteristics of soil, such as soil cover, humus content, colour, erosion reduction, and water retention. However, the physiochemical characteristics may require prolonged implementation of agroecological practices to yield detectable outcomes. For long-term soil health, it is vital to empower producers so that sustainability in implementing agroecological practices extends beyond the project life. Likewise, it is recommended that farmer-centred assessment be combined with laboratory analyses for a more holistic evaluation of agroecological performance on soil health.

1 Introduction

Agroecology is defined by the Food and Agriculture Organization of the United Nations (FAO) as “an integrated approach that simultaneously applies ecological and social concepts and principles to the design and management of food and agricultural systems. It seeks to optimize the interactions between plants, animals, humans and the environment while taking into consideration the social aspects that need to be addressed for a sustainable and fair food system” (FAO 2018). The 10 elements of agroecology as defined by (FAO 2018) and the 13 principles of agroecology as per the 14th report of the High-Level Panel of Experts (HLPE 2019) of the Committee on World Food Security (CFS) are well-aligned and complementary (Wezel et al. 2020), guiding diverse stakeholders along the path to agroecological transition. In the face of urgent, complex and interrelated food system challenges, the holistic and transformative approach of agroecology is gaining momentum among a range of food system actors, from local farmers and civil society organizations to global policymakers and investors. In Kenya, a diverse group of stakeholders collaborates through the Intersectoral Forum on Agrobiodiversity and Agroecology (ISFAA) to accelerate agroecological transitions in the country under the leadership of the Ministry of Agriculture and Livestock Development. The ISFAA, a member of the Agroecology TPP, is spearheading the development of a national agroecology strategy.

As agroecology gains momentum, there is growing interest in assessing both the degree of agroecological integration and the performance of agroecology, i.e. data and information on how agroecological a given system is, and the degree to which increasing agroecological integration results in better achievement of societal goals (Geck et al. 2023). Through a multistakeholder process, FAO developed the Tool for Agroecology Performance Evaluation (TAPE), which aims to address both objectives (Mottet et al. 2020). In the Measuring Agroecology and its Performance (MAP) project, the TAPE was applied in Benin, Ethiopia, Kenya and Madagascar in the context of the DeSIRA project Enhancing Soils and Agroecology for Resilient Agri-food Systems in Sub-Saharan Africa (ProSilience), which itself is embedded in the GIZ global project Soil Protection and Rehabilitation for Food Security (ProSoil).

Initiated in 2015, the ProSoil project aimed to enhance food security and address the impacts of climate change by restoring degraded farmlands through the implementation of climate-smart farming practices. Over the past eight years, the ProSoil project has significantly enhanced community capacities for agroecological transitions in three Kenyan counties – Bungoma, Kakamega and Siaya. Employing key practices such as agroforestry, conservation agriculture, soil and water management, integrated pest management, and policy advice, ProSoil has effectively collaborated with smallholder farmers, experts and decision makers, thus propelling a landscape transition towards agroecology in the region (GIZ 2021). Embedded within the ProSoil project, the new Enhancing Soils and Agroecology for Resilient Agri-food Systems in Sub-Saharan Africa (ProSilience) project, also implemented by GIZ, aims to build on ProSoil outcomes by advancing agroecological transitions to enhance a climate-relevant, productive and sustainable transformation of agriculture and food systems in low- and middle-income countries (GIZ 2020). Earmarked for implementation near ProSoil sites, but where ProSoil interventions have not been carried out, ProSilience sites proved to be a suitable comparison group for the study. To gain more detailed insights into the physiochemical soil characteristics of the 201 assessed farms, TAPE was complemented with the Land Degradation Surveillance Framework (LDSF) methodology of soil sampling and analytics. Furthermore, the MAP project played a crucial role in developing and implementing an innovative data management platform tailored for TAPE tasks, simplifying the overall process of field data entry and management.

The main objectives of this application of TAPE in the context of ProSoil /ProSilience, were:

1. To assess the degree to which participation in ProSoil activities resulted in an increased degree of agroecological integration at farm/household level.
2. To assess how participation in ProSoil activities resulted in differing multidimensional farm/household performance, taking the multifunctionality of agriculture into account.
3. To assess how agroecological integration at farm/household level correlates with multidimensional farm/household performance, taking the multifunctionality of agriculture into account.

The study findings underscore the significance of integrating agroecology into the pursuit of multidimensional societal goals. The strengths and weaknesses of such integration are highlighted, accompanied by key recommendations aimed at promoting sustainability within farming systems.

2 Methods

2.1 Sample size and sampling procedure for the MAP project

The research utilized a mixed sampling approach to select participants for the TAPE application, aiming for a total of 201 respondents and farms. This group was split into 101 for the experimental group and 100 for the comparison group (Figure 1). In selecting the experimental group, 8,000 ProSoil beneficiaries formed the sampling frame. Through purposive selection, farmers were chosen based on their consistent implementation of ProSoil initiatives since the project's inception, with exclusion criteria for those who joined the project after 2020 during which the COVID pandemic interrupted farming practices. This timeframe was chosen to exclude disruptions caused by COVID-19 to farm interventions, potentially affecting its impact on farm systems. For the remaining respondents in each county, sampling was conducted using randomly generated numbers. The number of respondents per county was determined in proportion to the number of ProSoil beneficiaries in each respective county.

The comparison group was initially intended to be from the newly established ProSilience affiliated households (Figure 2). However, since ProSilience's formative phase lacked a clearly defined sampling frame, regulated snowball sampling was adopted. This approach ensured adherence to preferred selection criteria while securing an entry point to unentered sites. In each of the six wards earmarked for ProSilience implementation, two contact persons per ward were identified, each proposing 10 farmers from their respective wards to guarantee diverse representation. The selected farmers were derived from different sub-locations (lowest administrative boundary) for even spatial distribution and representativeness.

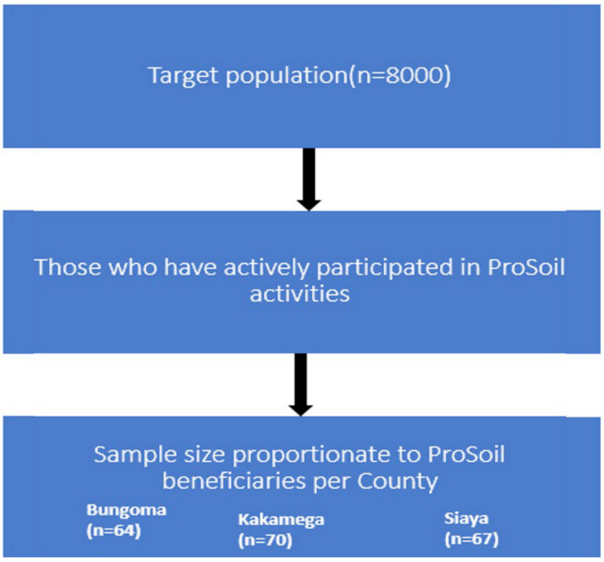


Figure 1. An illustration of the sampling procedure used to derive samples from ProSoil beneficiaries

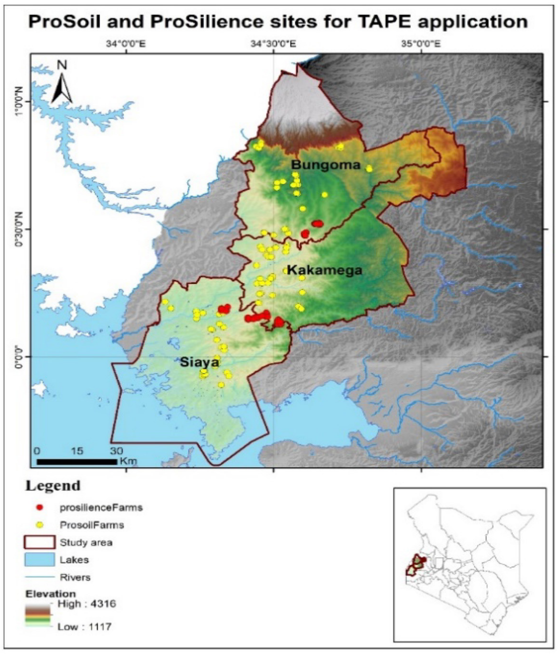


Figure 2. A map showing the sampled farms for TAPE application within ProSoil (represented by yellow dots) and comparison sites (represented by red dots). Farms not targeted for implementing ProSoil activities served as a comparison group

To ensure comparability between the experimental and comparison group sites, it is crucial to maintain homogeneity within agroecological zones. Therefore, sites in Bungoma near mountainous areas were excluded. This exclusion aims to minimize unnecessary discrepancies in the sampling process and allows for a focused assessment of the impact of ProSoil initiatives. The objective was to make sure that the challenges faced within these sites are as similar as possible, while still maintaining a clear distinction in the implementation of ProSoil interventions. Leveraging distinct wards within ProSilience-targeted areas, which mirror the agroecological zones found in ProSoil implementation sites, proves advantageous in achieving this comparability.

2.1.1 Soil sampling technique using the Land Degradation Surveillance Framework (LDSF)

The TAPE questionnaire was customized to offer comprehensive insights into soil health to determine the efficacy of ProSoil interventions as well as the contribution of agroecological integration in enhancing soil health. The Land Degradation Surveillance Framework (LDSF), developed by ICRAF, was applied in soil sampling and analytics to this effect. The LDSF provides a hierarchical sampling design, ensuring local relevance while creating predictive models with global applicability. In each of the 202 selected farms, a centroid point (sub-plot 1) was purposively selected as a good representation of the soil status in the entire productive farm under investigation (Figure 3).

An additional three sub-plots were then delineated at a maximum of 12.2 m, and distributed at 120, 240 and 360 degrees around the centroid sub-plot (Figure 3). Two composite soil samples; topsoil (0–20 cm) and subsoil (21–30 cm) were then extracted using soil augers from the four sub-plots, resulting in two soil samples per farm.

Likewise, the soil's microbial activities were assessed using hydrogen peroxide, and the outcome was evaluated on a qualitative Likert scale of 3. Soil samples were then analysed using a mid-infrared (MIR) spectroscopy technique combined with machine learning. Spectral measurements for the soil samples were acquired using a Bruker FTIR HTS-XT spectrometer fitted with a high-sensitivity liquid nitrogen-cooled mercury-cadmium telluride (MCT) detector. The prediction model was then validated using the wet chemistry method.

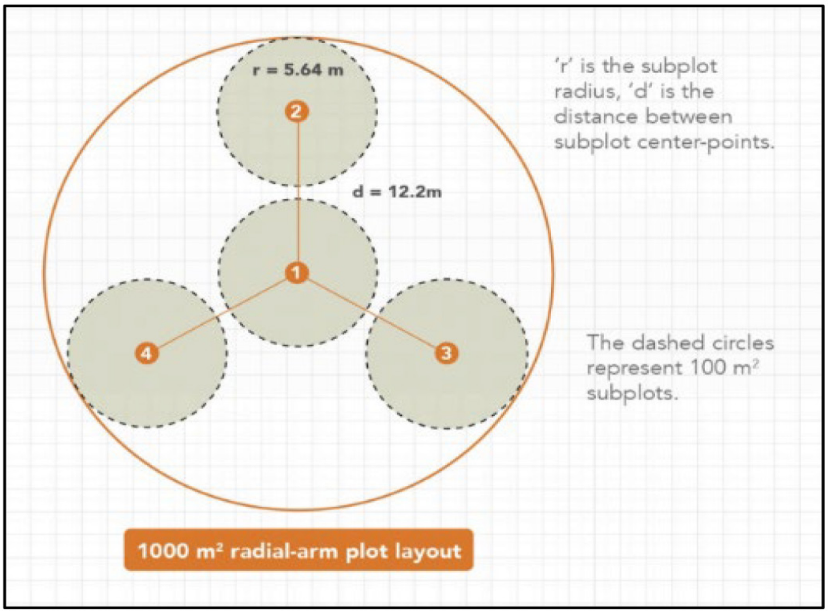


Figure 3. Soil sampling plot layout. Extracted directly from the ICRAF 2023 LDSF Field Manual
Source: https://www.cifor-icraf.org/knowledge/publication/25533

Figure 4. Enumerator training on the use of soil augers (left), and soil sampling process at one of the farms in Bungoma (right)
Photo by B. Adoyo/CIFOR-ICRAF

2.2 Data collection and analysis

2.2.1 Tool for Agroecology Performance Evaluation (TAPE)

The FAO's Tool for Agroecology Performance Evaluation (TAPE), a comprehensive global analytical tool for assessing the agroecological performance of farming systems, was utilized and applied to collect data from 201 farms in Bungoma, Kakamega and Siaya counties of Kenya, equally distributed among the ProSoil and comparison group. The TAPE questionnaire comprises four primary sections: Step 0 (context evaluation), Step 1 (characterization of the level of transition to agroecology), Step 2 (agroecological performance based on core criteria), and Step 3 (participatory interpretation of results). Each section offers complementary information that, when combined, provides insights into the extent and multidimensional effects of agroecology (Mottet et al. 2020).

Step 0 of TAPE is a preliminary step that provides context to the TAPE application by highlighting the socio-economic, demographic and biophysical context of the farming system under assessment. Step 0 also outlines the typologies of farming systems and the enabling environments for agroecological transition. Information on Step 0 is typically collected at a landscape, territorial or national scale through a desk review, with a few indicators such as farm size and household characteristics being obtained during the administration of the TAPE questionnaire.

Step 1 of TAPE, known as the Characterization of Agroecological Transition (CAET), involves characterizing the degree of a farm system's transition to agroecology based on the 10 elements of agroecology (Table 2). The findings of Step 1 of TAPE are intended to assess the level of agroecological transition, the strengths and weaknesses of farms being assessed, and the interrelationship between different elements of agroecology.

In Step 1, each element is assigned specific performance indices, which are scored on a semi-Likert scale ranging from 0 to 4, representing some graduated descriptive scales. The total scores for indices corresponding to each element are then aggregated and standardized on a scale of 1% to 100%. To derive the total CAET score, the standardized scores for all the 10 elements are averaged. Correlation coefficients are then calculated across all elements to understand the interrelationship between different aspects of agroecology.

Step 2 of TAPE evaluates agroecological performance against the indicators of sustainability that are related to sustainable development goals and are considered a priority for policymakers (Mottet et al. 2020). The comparison of Step 1 and 2 results provide evidence of the contribution that different elements of agroecology make towards achieving selected dimensions of sustainability.

Step 3 of TAPE is the final key step that contextualizes TAPE findings through a participatory interpretation of TAPE results by relevant stakeholders. This step is crucial in validating and reviewing the results of the previous three steps, and in evaluating the factors that contribute to the observed findings. Importantly, Step 3 entails the identification of synergies and trade-offs as well as suggestions on the practical actions needed to improve the performance of the CAET scores to accelerate agroecological transition.

2.2.2 TAPE application in the Kenyan context.

The application of TAPE in the three Kenyan counties was initiated through a series of meetings. These included an inception workshop and a kick-off gathering to create a common understanding of the project's objectives among actors, and to align project activities with the set timelines. The implementing team held bilateral meetings to deliberate and decide on the most appropriate sampling design. A team of 13 experienced enumerators from the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) was selected to apply TAPE in the three counties:

Table 1. Elements of agroecology and their associated indicators used in the characterization of agroecological transitions

No.	Dimension	Element of agroecology	Indicators
1	Agroecological practices	Diversity	Crop diversity
			Animal diversity (including fish and insects)
			Tree diversity (including other perennials)
			Diversity of activities generating income
2		Synergy	Crop/livestock integration
			Soil management system
			Integration of trees (agroforestry, silvopastoral, agrosilvopastoralism)
			Connectivity between elements of the agroecosystem and the landscape
3		Recycling	Recycling of biomass and nutrients
			Waste production and management
			Water recycling and saving
			Energy reduction and renewable energy
4	Emergent properties	Efficiency	Use of external inputs
			Management of soil fertility
			Management of pests and diseases
			Emerging efficiency from good practices
		Resilience	Existence of social mechanisms to reduce vulnerability
			Environmental resilience and capacity to adapt to climate change
			Emerging resilience from diversity
			Emerging resilience from self-sufficiency and empowerment

continue to the next page

Table 1. Continued

No.	Dimension	Element of agroecology	Indicators
5	Social dimensions	Culture & food tradition	Appropriate diet and nutrition awareness
			Food self-sufficiency
			Local and traditional food heritage
			Management of seeds and breeds
6		Co-creation and sharing of knowledge	Access to agroecological knowledge and interest of producers in agroecology
			Social mechanisms for the horizontal creation and transfer of knowledge and good practices
			Participation of producers in networks and grassroots organizations
			Co-creation and sharing of knowledge
7		Women's empowerment	Women's empowerment in decision making and access to resources
8		Human and social values	Labour (productive conditions, social inequalities)
			Motivation in agricultural work and continuity of family farming
			Animal welfare
9	Enabling environment	Circular & solidarity economy	Products and services marketed locally (or with fair trade)
			Networks of producers, relationship with consumers, and presence of intermediaries
			Local sourcing and circularity
10		Responsible governance	Producers' empowerment
			Producers' organizations and associations
			Inclusive decision-making processes

Source: Mottet et al. 2020

four enumerators in Bungoma, four in Siaya, and five in Kakamega. All enumerators underwent two days of training collaboratively facilitated by FAO, ICRAF and Stats4SD. Based on its wide-ranging experience, the FAO team took the enumerators through a step-by-step evaluation of each question in the TAPE questionnaire to acquaint them with the content and principles to be applied in administering each question. The enumerators identified areas that needed to be updated to fit the local context without changing the intended purpose. This led to some minor amendments, such as changing units of measurement. The training also encompassed soil sampling using the LDSF procedure, as well as the practical soil sampling process using the soil augers. This session was handled by the ICRAF soils team. Likewise, the Stats4SD team took the enumerators through a hands-on demonstration of data collection, recording and submission, using the open data toolkit. On the final training day, enumerators conducted a pretest of the entire questionnaire administration and soil sampling to assess the practicality of TAPE application and duration of questionnaire administration.

Although Step 0 typically utilizes secondary data, this study employed a combined approach, integrating information from secondary data (county reports, project reports and publications) with interviews involving four key informants from each of the three counties, to gather insights into the specific contexts of their respective sites. A key informant interview guide (Annex 1) was used to administer the open-ended questions, which were entered in an Excel spreadsheet and interpreted through content analysis. The selection of key informant interviews was guided by GIZ partners in each of the three counties, prioritizing relevant actors within the food system industry who were particularly knowledgeable about the local context and about how it impacts food systems.

Figure 5. Stakeholders who participated in the MAP results validation workshop at Ciala hotel in Kisumu County
Photo by Beatrice Adoyo

Step 3 comprised a one-day validation workshop attended by 46 stakeholders from diverse organizations, including representatives from government bodies, the private sector, non-governmental organizations, civil society, and farmers (Figure 5). In this workshop, the findings from TAPE Steps 0, 1 and 2 were presented for validation and open discussion. The facilitator fostered an environment conducive to discussion and assured participants of the value of each person's contribution, encouraging them to provide context to the observed findings based on their experiences. Further, participants were organized into four groups to explore how the local context and enabling environments described in Step 0 – along with their own experiences – could explain the observed findings. Subsequently, all participants engaged in a plenary session to share feedback and discuss the significant implications of the findings for decision makers, as well as to propose areas for enhancing agroecological performance.

2.2.3 Statistical analysis

The Spearman's rank correlation test was used to assess the relationship between performance indicators and both the total CAET score and each of the 10 agroecological elements. The Spearman's correlation coefficient (r) ranges from -1 to 1, with $\rho = 1$ indicating a perfect positive correlation (where one variable increases as the other increases, and vice versa), $\rho = -1$ indicating a perfect negative correlation (where one variable increases as the other decreases, and vice versa), and $\rho = 0$ indicating no correlation between the variables. The associated p-value determines the statistical significance of the correlation, with a small p-value (typically ≤ 0.05) indicating strong evidence against the null hypothesis, and a large p-value (> 0.05) indicating weak evidence against the null hypothesis. However, a comparison between households from ProSoil group and the comparison group was conducted using T-tests to assess the score difference between the two groups.

3 Results and discussions

3.1 Step 0 of TAPE: Context of TAPE application

This section highlights the context of TAPE application in the study area, focusing on the study sites' socio-economic, ecological and biophysical characteristics. It also examines the enabling factors that either facilitate or hinder agroecological transition. Step 0 of TAPE is conducted at a territorial level rather than at farm level and aims to contextualize the results observed in the subsequent steps of TAPE application.

3.1.1 Agroecological zones

The entire study area falls within five major agroecological zones: tropical alpine, upper highlands, lower highlands, upper midlands, and lower midlands. However, three of the five agroecological zones (alpine, upper highlands, lower highlands) are found only in Bungoma County, with the selected farms predominantly falling within the lower midland zones (Figure 6).

The low midland zones encompass the humid and sub-humid zones with reliable mean annual precipitation (650 mm–1,900 mm) at an altitude of 790 m to 1,500 m above sea level and experiencing a mean annual temperature of 21.8°C to 24°C (Table 2). A few of the farms from ProSoil group were in the upper midland zone. These are coffee and tea-growing areas, particularly in Bungoma County, which has high annual rainfall (1,800 mm–2,000 mm) with low mean annual temperatures ranging from 18.5°C to 21°C.

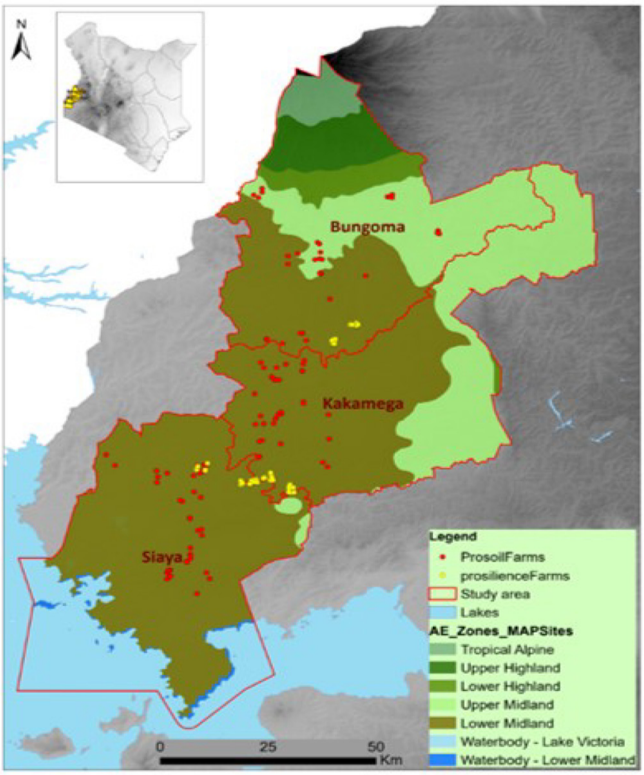


Figure 6. Agroecological zones within the study area

The upper midland zone experiences variability in rainfall, resulting in low, but rarely critical, reliability. Observations from the Siaya County agricultural officer indicate that the highland regions are more degraded, leading to a greater dependence on mineral fertilizers compared with the lowlands. Consequently, the highest proportion of farmers utilizing mineral fertilizers (75%) was found in Bungoma County (Figure 7), which falls predominantly within the upper midland regions.

This phenomenon is linked to the elevated population density in the highlands, where small land parcels contribute to intensive land use. Additionally, the erosion of top fertile soils due to unsustainable farming practices was perceived to result in the deposition of fertile soils in lowland areas, reducing their reliance on external fertilizers.

Table 2. Agroecological zones in Siaya County

Agroecological zones (AEZ)	Altitude (m)	Annual mean temperatures	Annual average rainfall (mm)	60% reliability of rainfall (mm)	
				Long rains	Short rains
Lower midlands (LM1)	1,300–1,500	21.8°C–20.9°C	1,500–1,900		
Lower midlands (LM2)	1,337–1,457	22.3°C–21.5°C	1,400–1,600		
Lower midlands (LM3)	1,160–1,350	22.7°C–22.0°C	1,020–1,390	250–350	250–350
Lower midlands (LM4)	1,160–1,280	22.7°C–22.3°C	890–1,020	220–350	250–350
Lower midlands (LM5)	790–1,220	24.0°C–21.6°C	650–750	180–300	200–300

Source: County Government of Siaya, 2023

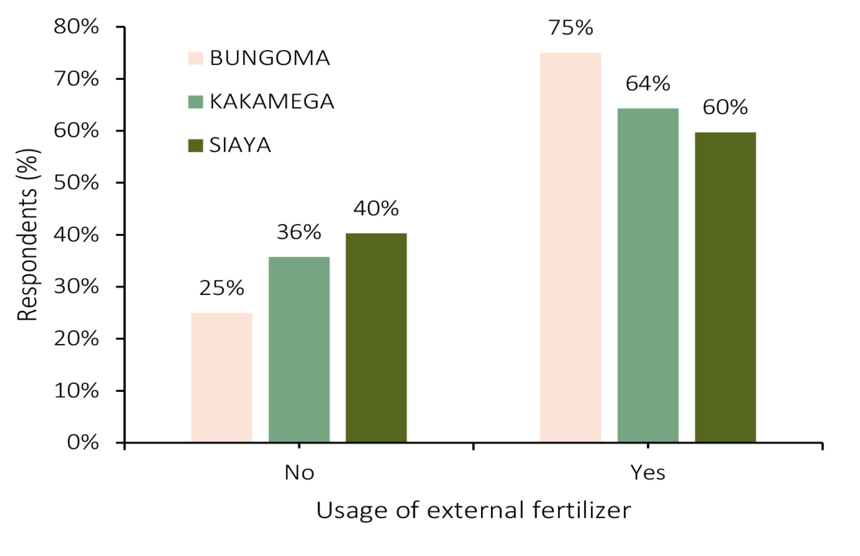


Figure 7. The usage of external fertilizer in Bungoma, Kakamega and Siaya Counties

3.1.2 Climatic conditions

The climatic conditions within the three counties have been increasingly unreliable and variable over the years due to climate change, according to key informants' responses provided in November 2023. Bungoma County has an altitude ranging from 1,200 m to the west and northwest regions, to 4,321 m to the north within the Mount Elgon area. The annual temperature in the county varies from 0°C to 32°C due to different levels of altitude, with the highest peak of Mount Elgon recording slightly less than 0°C. Kakamega County has a tropical climate with rainfall ranging from 1,280 mm to 2,214 mm per year owing to its proximity to the Kakamega Forest. While heavy rains fall from March to July, there are lighter rains from December to February. The temperatures range from 18°C to 29°C (County Government of Kakamega 2023). Siaya County is generally hot and moist with mean monthly temperatures of 21°C to 25°C and a steep rainfall gradient. The northern part experiences more than 1,700 mm annual rainfall, while the southern lowlands around Lake Victoria receive 1,000 mm to 1,250 mm annually (County Government of Siaya 2023).

3.1.3 Demographic characteristics

Out of the three counties considered in the study, Kakamega has the highest population and has been categorized as the fourth-most-populous county out of the 47 counties in Kenya. According to the latest census report (KNBS 2019), Kakamega had a population of 1,867,579 – of whom 48% were male and 52% female – and a population density of 674 persons per square kilometre. Bungoma

County has a population of 1,670,570 people (3.5% of the Kenyan population), while Siaya is the least populous of the three counties, with a population of 993,183 in the latest census – 47.5% were male and 52.5% were female – and an average population density of 410 people per square kilometre (KNBS 2019). According to the TAPE Step 0 results, most farmers from both ProSoil (63%) and comparison (72%) groups, live below the international poverty line, which is set at USD 2.15 per day based on 2017 standards (Jolliffe et al. 2022).

3.1.4 Farming systems and typologies

Most farmers in the study area practice subsistence farming on a small scale on farms that average 0.7682 ha (Step 0 of TAPE survey), with most farmers (about 40%) operating on farms less than 2 ha (Figure 8). Overall, the data highlight variations in farm sizes across the three locations, with Bungoma having the largest farm sizes (averaging 0.9 ha), followed by Kakamega (0.8 ha), and Siaya (0.7 ha)

The main economic activity is agriculture, particularly mixed farming for household consumption, with the surplus being sold locally. The predominant crops cultivated include maize, beans, fresh vegetables, bananas, sweet potatoes and various fruits – in descending order – all of which enjoy a thriving market within the region. Similarly, the prevalent livestock raised in the area consists of cows/bulls, chickens, goats and sheep (Figure 9), primarily for their outputs such as milk, beef and eggs, which fetch convenient sales and income.

The TAPE farm transition typologies involve clustering farms according to their progression towards agroecology, allowing for the assessment of CAET performance within specific farming system clusters. Although this classification wasn't conducted with direct participation, we adopted verified typologies developed by Lucantoni et al. (2022), who suggested clustering farm typologies based on their transitional levels. Consequently, with CAET scores below 50% considered as non-agroecological, those scoring 50% to 60% are at an incipient transition, while farms with scores of 60% to 70% should be classified as transitioning to agroecology. Advanced agroecological farms score above 70% on the CAET scale. This scale was adopted in assessing the level of agroecological transition in Step 1 of TAPE.

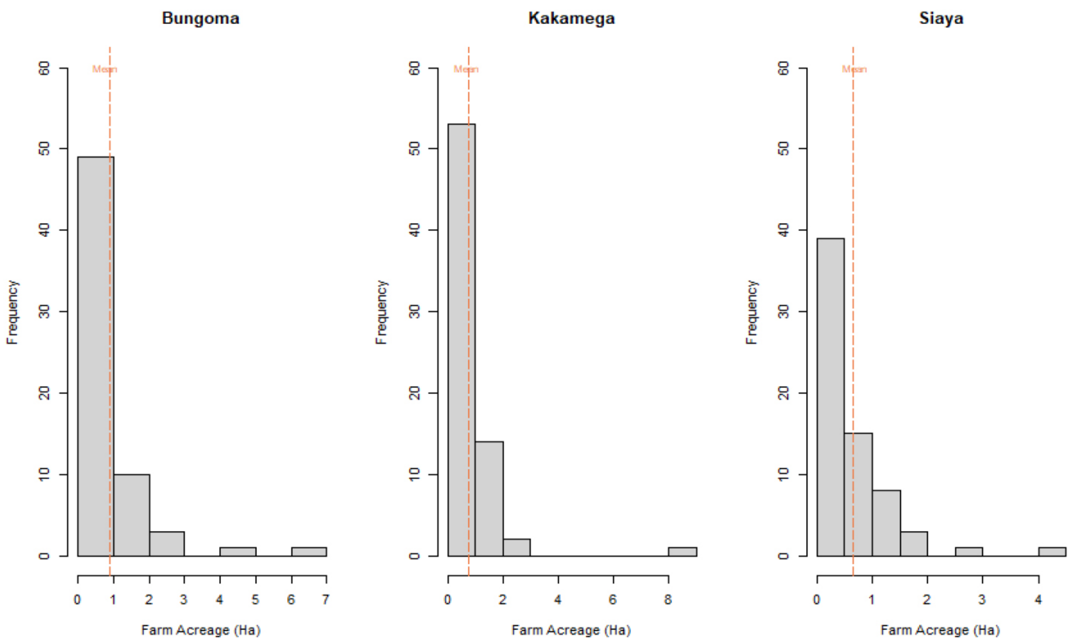


Figure 8. The distribution of farm sizes in Kakamega, Bungoma and Siaya Counties. The dotted lines represent the mean farm size.

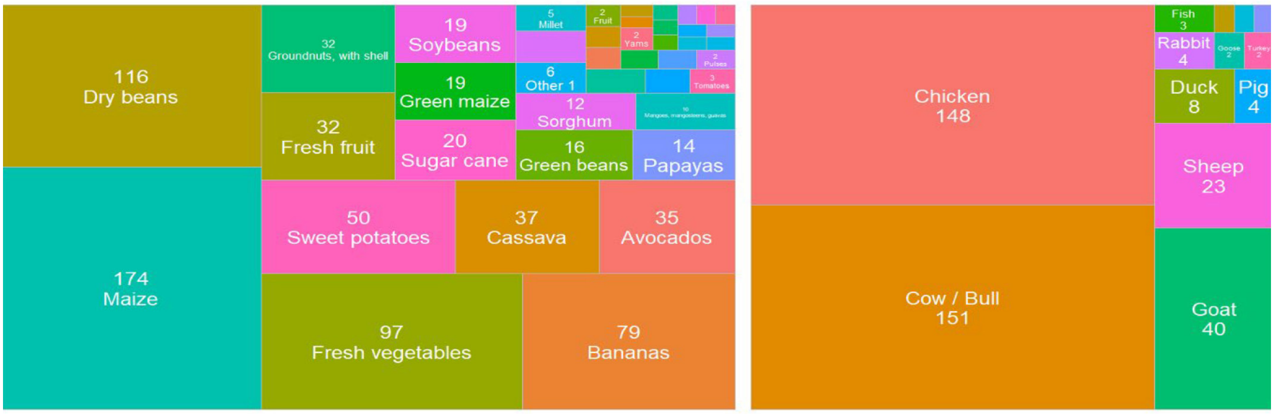


Figure 9. A tree map showing the types of crops grown (left) and animals reared (right) in the study area. The size of the boxes is representative of the number of households; the values in each box indicate the actual number of households (out of the 202 households) cultivating a particular crop or rearing a given type of animal.
Source: Step 0 of TAPE survey results

3.1.5 Youth involvement in agriculture

While youth constitute the largest segment of the labour force in western Kenya, most of them were perceived to consider farming as a less lucrative economic pursuit compared with more prominent enterprises, like motorcycle transportation, sand harvesting, poultry farming, establishing tree nurseries, and engaging in fishing, according to key informants' responses provided in November 2023. The limited ability to fully harness youth involvement in agriculture is linked to the belief that farming offers unstable employment prospects, characterized by extended waiting periods to realize benefits. Moreover, uncertainties arise from the lack of ownership of the land they cultivate, potentially resulting in the loss of benefits derived from their efforts (Siaya County 2020). Furthermore, the prevailing stereotype that associates farming with punishment for low achievers, even in the school setting, contributes to youth's reluctance to pursue agriculture.

3.1.6 Marketing conditions

Apart from the cash crops – like sugarcane – that target processing industries, most farm produce is locally marketed, particularly at the farm gates in Siaya and Kakamega Counties. The case is slightly different in Bungoma County, where the Chwele inter-county market helps Bungoma producers to sell their produce beyond the county boundary. Despite low prices associated with this approach, attempts to organize farmers and aggregate their produce in search of better market prices have been unsuccessful. While small-scale production from typically small farms in the region may not satisfy organized markets, farmers are often inadequately involved in the organization of aggregated market plans, jeopardizing optimal utilization of established market aggregation centres. Likewise, the area faces the challenges of unfavourable market conditions and deficient infrastructure, such as poorly developed roads and markets. This compels farmers to rely on middlemen who exploit them, and fetch produce at low prices. Owing to high market prices for farm inputs, most low-income farmers have embraced the use of locally available materials, such as organic fertilizers and biopesticides (e.g vermi juices). However, the inadequacy of raw materials poses a challenge to agroecological transitions.

3.1.7 Key challenges facing farming practices

Some of the primary obstacles to agrifood production in the study sites, as identified by key informants, include land degradation, market uncertainties, inadequate access to organic farm inputs, and the adverse impacts of climate change manifested in erratic rainfall patterns, and shifting climatic conditions, which have intensified the prevalence of pests and diseases. These obstacles have a detrimental effect on the productivity and profitability of farming activities. Additionally, land degradation emerged as a significant challenge, leading to an excessive reliance on external farm inputs that are both costly and contribute to further land degradation. Specifically, in Kakamega County, the prolonged and excessive application of mineral fertilizers on sugarcane farms – the primary cash crop – was recognized as the main cause of extensive land degradation and food insecurity. Before the collapse of the major sugar companies in the region, communities opted to plant the cash crop due to its economic benefits, resulting in fewer farms dedicated to food crops, thus increasing dependence on external markets. Moreover, weak governance policies were identified as obstacles to agroecological transitions. The county government's efforts to boost productivity by providing subsidized fertilizers, and to mechanize agriculture through the procurement of ploughing tractors – leased to farmers at subsidized rates – raise concerns about the sustainability of agricultural practices, particularly within vulnerable farming systems. Despite the intended goal of facilitating intensive agriculture and improving farm productivity, these incentives might pose sustainability challenges, potentially jeopardizing the future realization of desired benefits.

3.2 Step 1 of TAPE: Characterization of Agroecological Transition (CAET) in Kenya

This section provides evidence on the level of agroecological transitions among the ProSoil and the comparison group by assessing their degree of agroecological integration across the 10 elements of agroecology. The CAET scores generally indicate that the shift towards agroecological farming systems in the study area is still in its nascent stages. This is demonstrated by the low average CAET score of 53%, with 75% of the farms scoring below 68% in terms of agroecological transition.

Farms of the ProSoil participating households showed higher levels of agroecological transitions, having an overall mean CAET score of 67% and mean scores of 70%, 67% and 64% for Siaya, Kakamega and Bungoma, respectively (Figure 10). In contrast, the comparison group exhibited a notably low mean CAET score of 38%, with median scores ranging from 30% to 45% across the three counties examined in the study (Figure 10). This observation highlights that farms from the comparison group are predominantly non-agroecological (CAET<50%), while those from the ProSoil group have either progressed or are in the incipient stages of transitioning towards agroecology. Additionally, the variance in agroecological integration between ProSoil and comparison groups remained consistent across all three study sites (Bungoma, Kakamega and Siaya), indicating a positive effect of the ProSoil project activities on agroecological transitions (Figure 10). The level of agroecological integration within farms belonging to the ProSoil group was mostly clustered around or exceeded the median score, while the comparison group tended to fall below the median score, with only a few surpassing it. Consequently, while transition efforts among households participating in ProSoil activities should focus on a small portion of their underperforming farms, a significant proportion of the comparison group would need transformation to progress in agroecological transitions.

Despite the disparity in the level of agroecological integration between the two groups, outliers among the comparison group were noted to have remarkably high CAET scores (above 70%). This indicates that a few of the farms that are not direct beneficiaries of ProSoil activities are also trying to integrate the elements of agroecology into their farming systems.

Notably, the level of agroecological integration is inversely correlated with farm size, since the CAET score decreases with an increase in farm size (Figure 11). Consequently, smaller farms demonstrate a more advanced transition to agroecology than larger ones. This finding is consistent with Liebert et al. (2022), who found that organic and agroecological farm practices are more likely to be implemented on smaller farms than large ones. This trend may be attributed to limited access to agroecological inputs, such as organic fertilizers and biopesticides, posing a challenge in implementing agroecology on a larger scale. Therefore, the intensification of agroecological practices is prioritized on small-scale farms that align with the available limited resources.

On average, households participating in ProSoil activities demonstrate a higher level of agroecological integration across all 10 elements of agroecology when compared with the comparison group (Figure 12). This finding implies a more holistic contribution of ProSoil activities in achieving a sustainable farming system through the integration of diverse elements of agroecology.

ProSoil group achieved the highest scores in agroecological integration for efficiency (CAET=74%) and recycling (CAET=73.8%; Figure 13), whereas responsible governance (CAET=57.8%) and resilience (CAET=59.7%) had the lowest scores (Table 3). Likewise, the difference between the two groups was particularly pronounced regarding the elements of efficiency (CAET score difference of 40%), co-creation and sharing of knowledge (CAET score difference of 36%), recycling (CAET score difference of 33%), and synergies (CAET score difference of 30%; Figure 13). This indicates that while ProSoil activities tend to capitalize on minimizing external inputs and optimizing the use of locally available resources (Figure 12), they are less focused on social mechanisms to reduce vulnerabilities and adapt to natural disturbances, such as climate change impacts.

Likewise, their empowerment of producers in decision making and natural resource governance is limited. Despite households implementing ProSoil interventions being drawn from existing farmer organizations, the low score on responsible governance underlines the necessity to enhance the bargaining power of both genders in democratic decision making on the access and management of resources. Further, the low score on resilience can be attributed to the high poverty levels, illustrated by a large proportion (63%) of ProSoil group living below the international poverty line, set at $2.15 per day (Hasell 2024). Coupled with cases of market uncertainties and degraded soils, farmers' capacity to recover from disturbances is compromised, resulting in the observed low resilience within their farming systems.

3.2.1 Correlation among the different elements of agroecology

The assessment of correlations among different elements of agroecology is key in evaluating synergies or trade-offs among them and designing more effective strategies for sustainable and resilient farming systems. Since all elements contribute to the aggregate CAET score, a strong positive correlation ($r>0.8$; $p<0.001$) was detected between the total CAET score and each of the 10 elements of agroecology within the study area (Figure 14). In comparing the interrelationship between individual elements of agroecology, no negative correlation existed between any two elements, indicating a synergistic relationship among all the elements of agroecology (Figure 14). This highlights the significance of the aggregate contribution of each element to the overall agroecological transition and thus the need to equally emphasize the integration of each element in advancing agroecological transition.

Further, the findings highlight elements that had the greatest contributions to the total CAET scores, thus providing entry points on areas to focus on in maximizing the potentiality of agroecological transition in the study area.

The elements of efficiency ($r=0.89$, $p<0.001$), synergy ($r=0.89$, $p<0.001$), and the co-creation and sharing of knowledge ($R=0.87$, $p<0.001$***) exhibited the strongest correlations and therefore contributed most significantly to the CAET score (Figure 14). Consequently, the co-creation of knowledge on the most efficient use of locally available resources – through an approach that enhances the synergistic integration of crops, animals and trees within a connected landscape – was found to have the greatest impact on advancing agroecological integration.

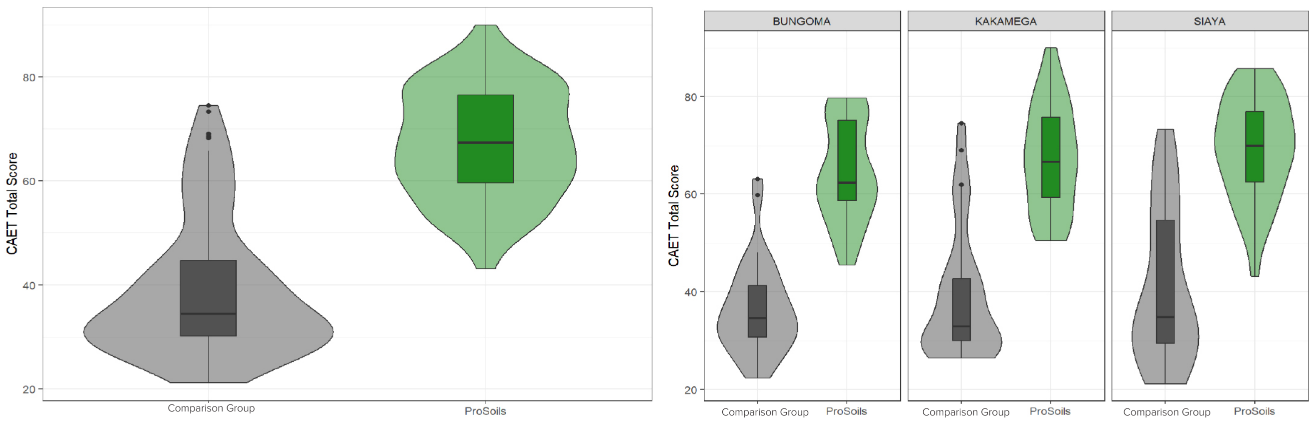


Figure 10. Level of agroecological transition as defined by the total CAET score (left) and across the three counties (right). The total CAET score on the y-axis indicates the overall level of agroecological integration across the 10 elements of agroecology.

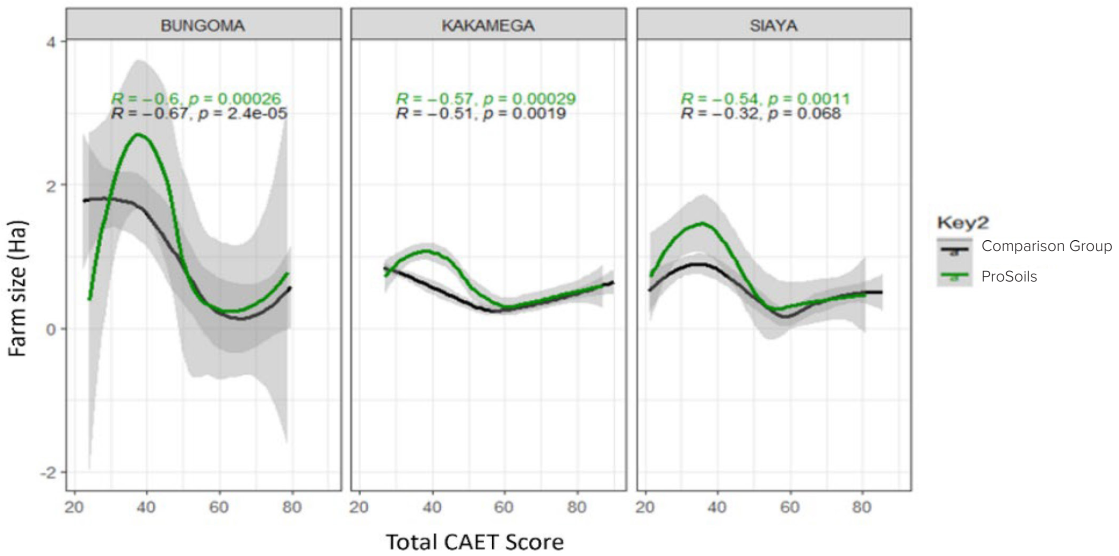


Figure 11. Correlation between the level of agroecological transition and farm size (ha) disaggregated by ProSoil and the comparison groups. 'R' represents the Spearman correlation coefficient while the p-value is the probability of observing the calculated correlation coefficients.

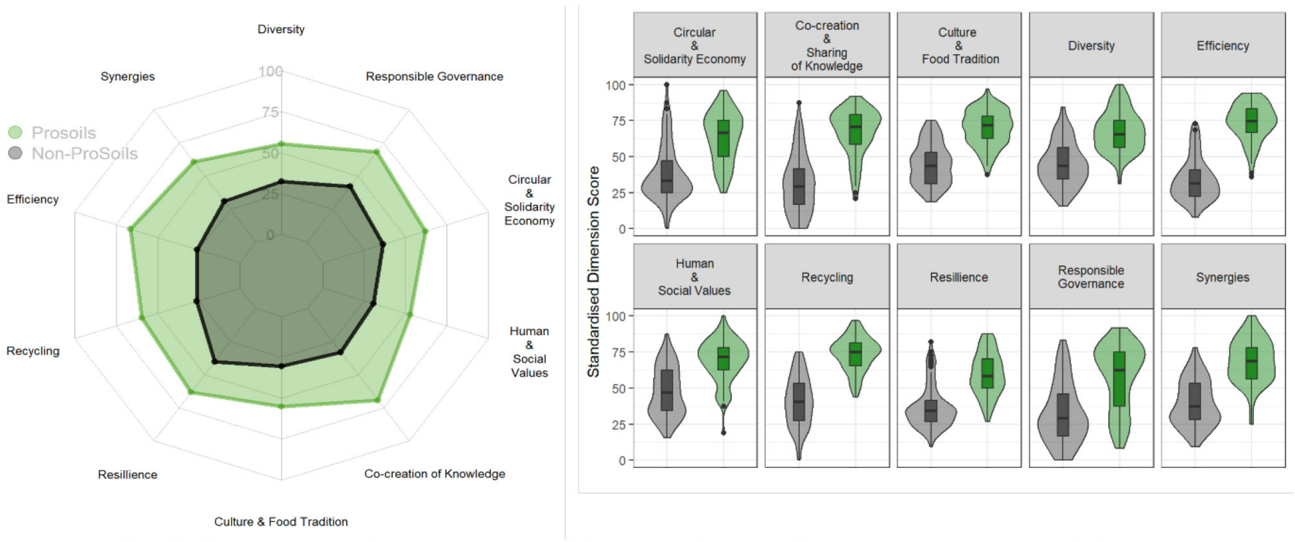


Figure 12. The level of agroecological transition across elements of agroecology between ProSoil and the comparison group. The figures illustrate that farms from the ProSoil group had higher scores on all elements of agroecology compared with the comparison group.

Figure 13. Production of composted manure on one of the farms where ProSoil interventions is being implemented in Kakamega County, illustrating the agroecological elements of recycling and synergy

Photo by Kevin Magwilu

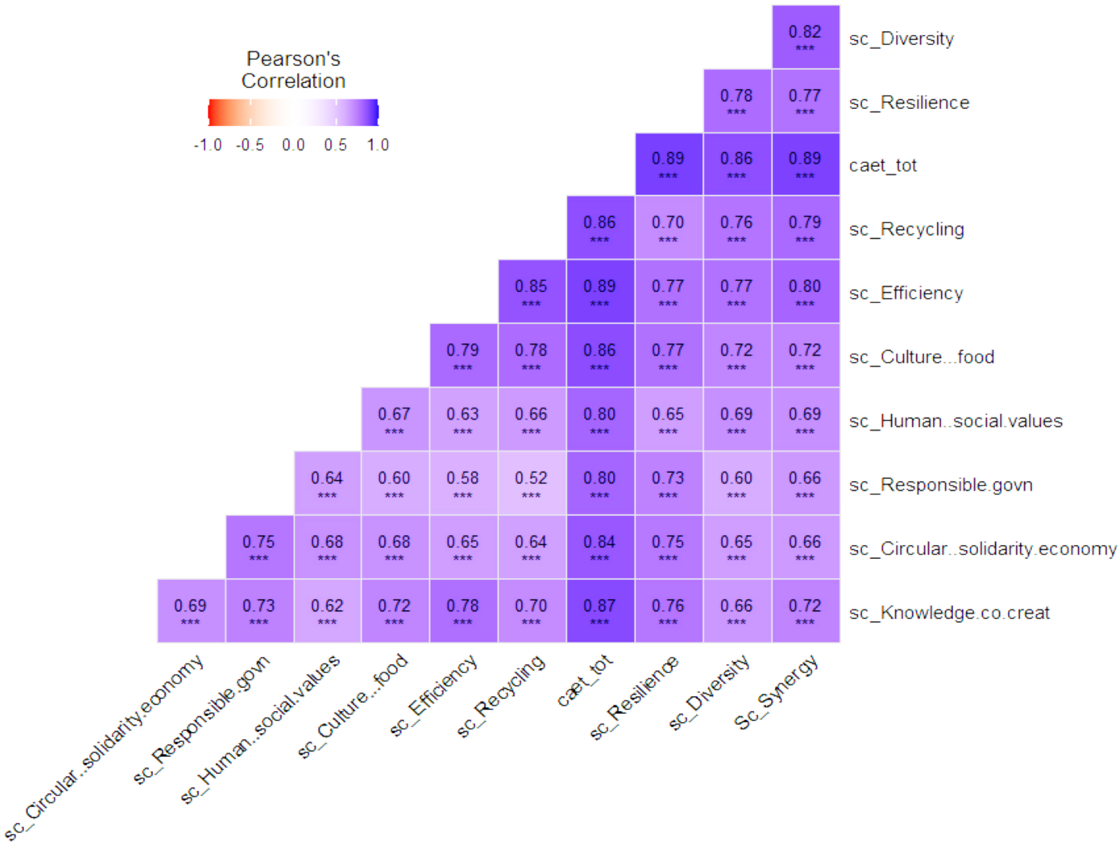


Figure 14. Correlation among elements of agroecology in the study site. Values in each box represent the Spearman correlation coefficient showing the strength of association, while the stars (*) represent the p-value indicating the probability of observing the calculated correlation coefficients.

Table 3. Level of agroecological transition across the 10 elements of agroecology disaggregated by ProSoil and the comparison group. The difference in the CAET scores indicates how far apart the two groups are in integrating agroecology on their farms.

Dimension	CAET score for comparison group	CAET score for ProSoil group	Difference in CAET scores	t-value	p.value***
Co-creation & sharing of knowledge	30.7	67	-36.2	-14.1	0.000***
Responsible governance	31.9	57.8	-25.8	-8.5	0.000***
Efficiency	33.8	74	-40.1	-20.7	0.000***
Resilience	36.7	59.7	-23.1	-11.1	0.000***
Circular & solidarity economy	38	63.5	-25.4	-9.9	0.000***
Synergies	39.2	68.9	-29.7	-13.6	0.000***
Recycling	40.7	73.8	-33.1	-16	0.000***
Diversity	44.8	67.6	-22.8	-11	0.000***
Culture & food tradition	44.9	69.6	-24.6	-13.1	0.000***
Human & social values	47.2	69.3	-22.2	-10	0.000***

Note: Not significant (ns) p>-0.05; *p<0.05; **p<0.01; ***p<0.001

3.3 Step 2: Multidimensional performance of agroecology

This section expounds on the contribution of agroecological intensification to the advancement of different sustainability dimensions (Annex 2). It provides insights into the role of agroecology and the contribution of ProSoil interventions to the performance of multidimensional societal goals aligned with sustainable development goals.

3.3.1 Correlation between CAET score and indicators of economy

Generally, a higher level of agroecological integration in farming systems was significantly associated with increased farm productivity (r=0.2, p<0.05) per hectare (ha) and per person (r=0.2, p<0.01), higher income from farming activities, and enhanced wealth creation (added value) from farming systems (r=0.26, p<0.01). Similarly, an increased CAET score was likely associated with increased farm wage expenses (r=0.14, p<0.05) and expenses on farm inputs, such as seeds, fertilizers, pesticides and machinery (r=0.14, p<0.05).

Despite a positive correlation between the overall CAET score and productivity per hectare (r=0.2, p<0.05, a temporary decline in productivity per hectare is observed during the transition to agroecology as the CAET score approaches the 70% threshold (Figure 15). This finding is consistent with previous research (Ong and Liao 2020), which found that in the early stages of transitioning to agroecology, there is often a temporary decrease in yields due to the time required for soil health to improve and beneficial ecological interactions to become established. Likewise, the initial stages of agroecological transition emphasize the promotion of multidimensional benefits, such as enhancing farm biodiversity, improving efficiency, and building resilient systems through a collective learning process that prioritizes the attainment of long-term sustainability over short-term productivity gains (Ong and Liao 2020; Sachet et al. 2021). This focus may lead to a temporary decline in gross output value per hectare until farmers adapt and develop robust resilience, after which a significant increase in productivity and sustainable yields is achieved (Figure 15).

The increase in gross output value (productivity) per hectare as the CAET score increases – particularly beyond a CAET score of 70% – is more pronounced in households participating in ProSoil activities. These households exhibit, on average, a higher overall productivity per hectare (KES 926,932) compared with the comparison group (KES 672,213). Although this difference is not

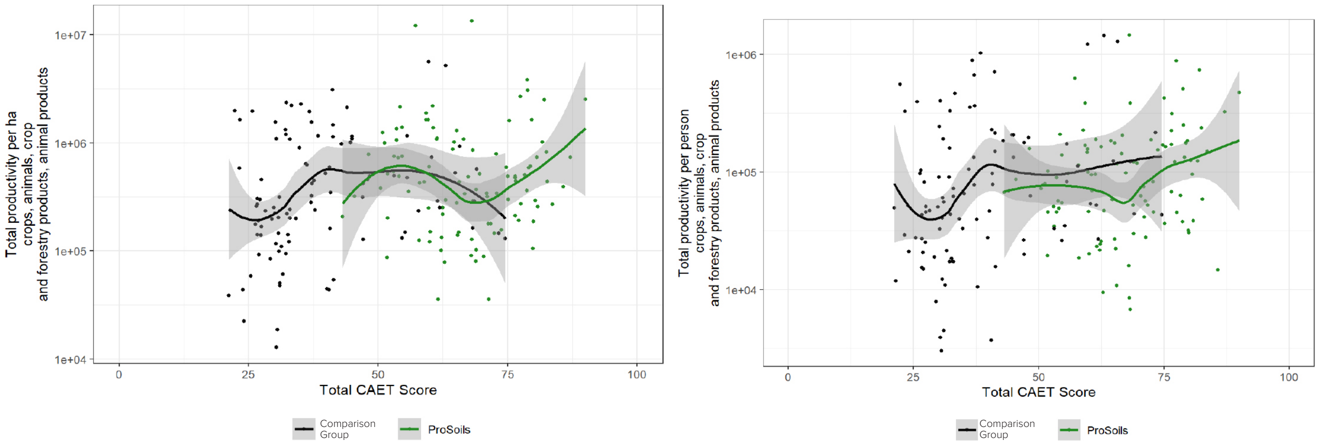


Figure 15. Correlation between CAET score and farm productivity per hectare (left) and per person (right) disaggregated by ProSoil, and the comparison group

statistically significant (p=0.2), it implies that participants in ProSoil activities are likely to achieve higher productivity per hectare.

Despite the above-mentioned observation, the number of people needed to realize the same gross output value was observed to be higher among ProSoil group compared with the comparison group. A unit increase in CAET score results in lower productivity per person among ProSoil group (r=0.2, p<0.001) compared with the comparison group (r=0.3, p<0.001). Additionally, beneficiaries of ProSoil interventions have slightly lower mean productivity per person (KES 145,639.3) compared with the comparison group (KES 164,238.3). Despite the potential for higher gross output value per hectare, implementing agroecological farming practices – which is the focus of the ProSoil project – is more labour-intensive than conventional farming (Baum et al. 2023), thus translating into lower productivity per person.

The results illustrate a positive correlation between farmers' perceived incomes and CAET scores (r=0.64, p<0.001). Thus, farmers perceive that as they advance in their agroecological integration, they are likely to earn more than they spend (Figure 16). These findings associate a net positive economic return with the integration of agroecology into farming systems, suggesting that agroecology is an economically viable practice. This perception is prevalent among farmers implementing ProSoil interventions, who reported higher perceived earnings (score = 4.1) associated with an increase in the CAET score, compared with the comparison group (score = 3).

Despite the perceived increase in net incomes with higher CAET scores, the positive correlation between the CAET score and expenditure on farm inputs (Figure 17) is supported by findings of a systematic review by Sachet et al. (2021). This review underscores that – besides investments in social processes – the intensification of agroecological practices necessitates investments in material inputs to facilitate a transition that ultimately translates into long-term sustainability and productivity gains.

A significant association between CAET score and input expenditure was observed among the comparison group (r=0.3, p<0.05), who recorded higher average expenditure on farm inputs (KES 73,046.8) compared with ProSoil group (KES 63,846.7). While investing in farm inputs is essential for advancing agroecological transitions, implementing ProSoil practices potentially reduces this cost, likely due to the adoption of agroecological farming practices (recycling and synergy), which reduce reliance and expenditure on externally sourced inputs.

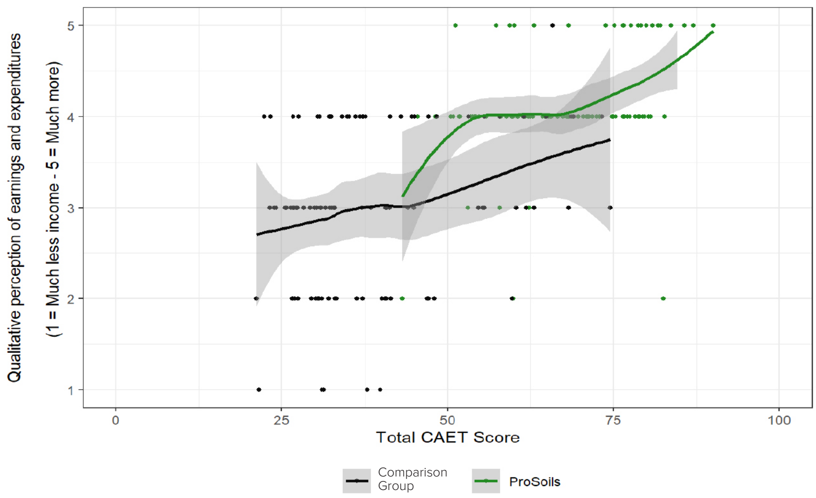


Figure 16. Correlation between CAET score and perceived net income, considering expenditures by ProSoil and the comparison groups. An increase in the level of agroecological integration is perceived to yield more income from farm produce, especially among farmers implementing ProSoil interventions.

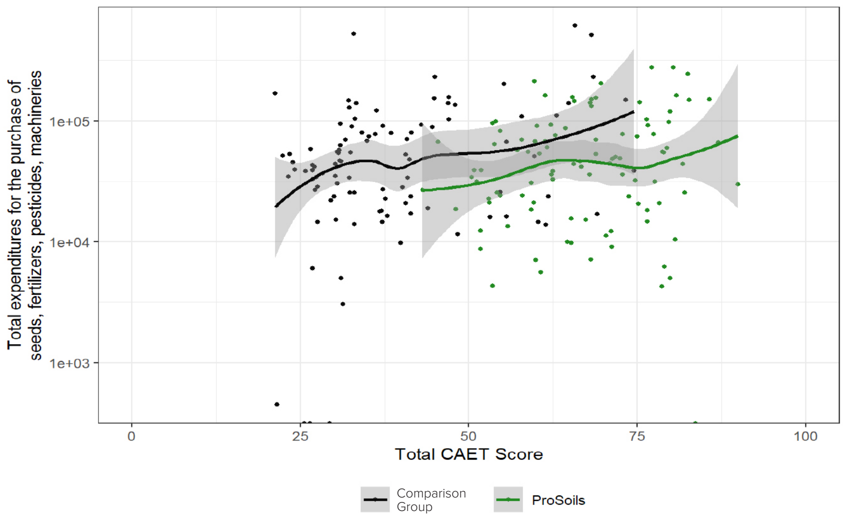


Figure 17. Correlation between CAET score and the total expenditure on farm inputs among ProSoil and the comparison group. Despite an increasing trend in input expenditure with CAET score, farmers participating in ProSoil interventions are likely to incur fewer expenses on farm input.

3.3.2 Correlation between CAET score and environmental indicators

In this section, we examine the effect of agroecological transitions and ProSoil interventions on environmental outcomes. Our evaluation of environmental indicators centres on measures such as agrobiodiversity (using the Gini-Simpson index for crops, animals, natural vegetation and pollinators) and soil health. For soil health assessment, we compare results obtained from the TAPE evaluation with those from the LDSF assessment, which relies on soil sample analysis.

The results of this research demonstrate a positive correlation between the overall CAET score and agrobiodiversity measures, specifically the Gini-Simpson index for crops ($r=0.39$, $p<0.001$), animals ($r=0.3$, $p<0.001$***), as well as natural vegetation and pollinators ($r=0.5$, $p<0.001$). Moreover, the CAET score positively correlates with overall soil health ($r=0.5$, $p<0.001$), focusing on biophysical indicators assessed through the TAPE tool, including soil cover, depth, compaction, water retention capacity, microbial activity, colour, odour, and organic matter. These findings highlight that integrating agroecological practices enhances biophysical soil health (Amoak et al. 2022) and agrobiodiversity (Villavicencio-Valdez et al. 2023), both of which play crucial roles in ensuring food and nutritional security (Fernandez and Ernesto Méndez 2018).

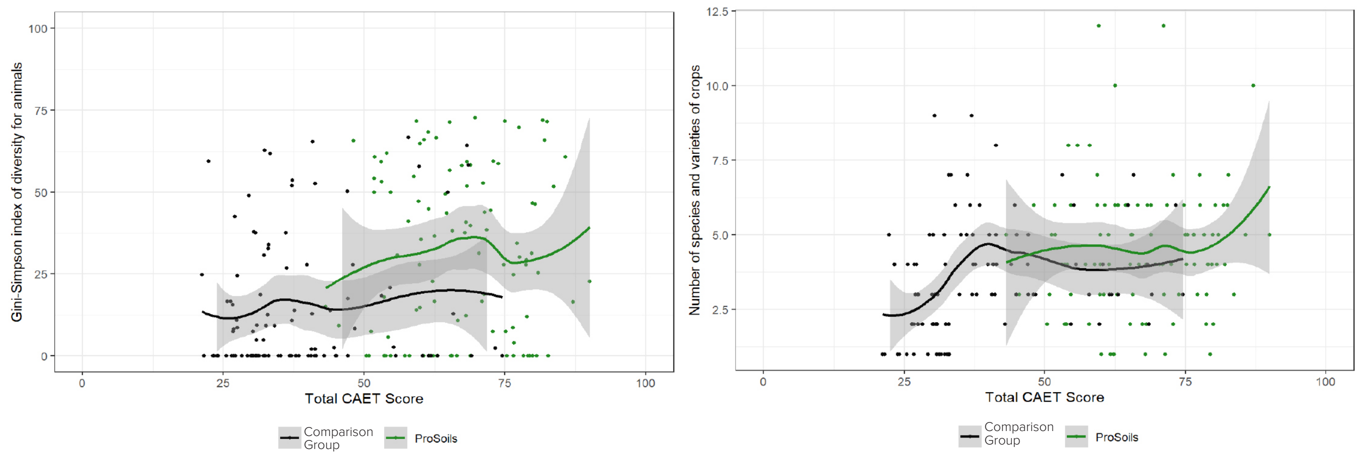


Figure 18. Correlation between CAET score and diversity indices for animals (left), and crop varieties and species (right). The positive correlation is expected as crop and animal diversity are key indicators in assessing the total CAET score.

In comparing the two groups considered in the study, the ProSoil group reported higher diversity scores than the comparison group, reflecting the ProSoil project's focus on farm diversification, among other agroecological farm practices (Figure 18).

The animal diversity index was positively correlated with recycling ($p<0.1$), suggesting that as farms diversified their animal population (Figure 19), they were more likely to engage in recycling practices. However, it was noted that the CAET score for animal diversity is negatively correlated with all the agroecological elements within the social domain: culture and food tradition ($r=-0.076$), co-creation and sharing of knowledge ($r= -0.075$), human and social values ($r= -0.006$), circular and solidarity economy ($r= -0.023$), and responsible governance ($r= -0.035$). It is assumed that being primarily an agrarian community with limited farm sizes, the elements of cultural traditions, and governance structures may not have been proactive in promoting animal diversification. This may be due to insufficient land resources to support large herds of animals, and inadequate knowledge about the potential positive impact of efficient animal diversification on agricultural performance.

The Gini-Simpson diversity index for natural vegetation and pollinators shows a positive correlation with both the overall CAET score and all elements of agroecology (Figure 20). This indicates that agroecological progress – characterized by a heterogeneous landscape rich in agricultural biodiversity – is crucial for stabilizing ecosystem processes such as pollination, which depends on the complex interactions between plants and animals for optimal ecosystem functioning (Astegiano et al. 2024). This correlation was higher among ProSoil group ($r=0.4$, $p<0.001$) compared with the comparison group ($r=0.3$, $p<0.01$).

Within farms from the ProSoil group, the presence of natural vegetation and pollinators positively correlates with elements of diversity ($r=0.3$, $p<0.001$), synergy ($r=0.4$, $p<0.001$), resilience ($r=0.4$, $p<0.001$), human and social values ($r=0.4$, $p<0.001$), and responsible governance ($r=0.4$, $p<0.001$). The high scores among ProSoil participating households on these elements therefore contributed to the increased diversity of natural vegetation and pollinators.

Regarding the contribution of agroecological integration to soil health based on TAPE analysis results, we found that the CAET score positively correlates with improved overall soil health (Figure 21), taking into account biophysical soil characteristics such as structure, soil cover, colour, water retention capacity, soil compaction, soil erosion, and soil microbial activity.

Figure 19. A farmer belonging to the ProSoil group in Kakamega County rearing diverse animals, reflecting the elements of animal diversity

Photo by Kevin Magwilu

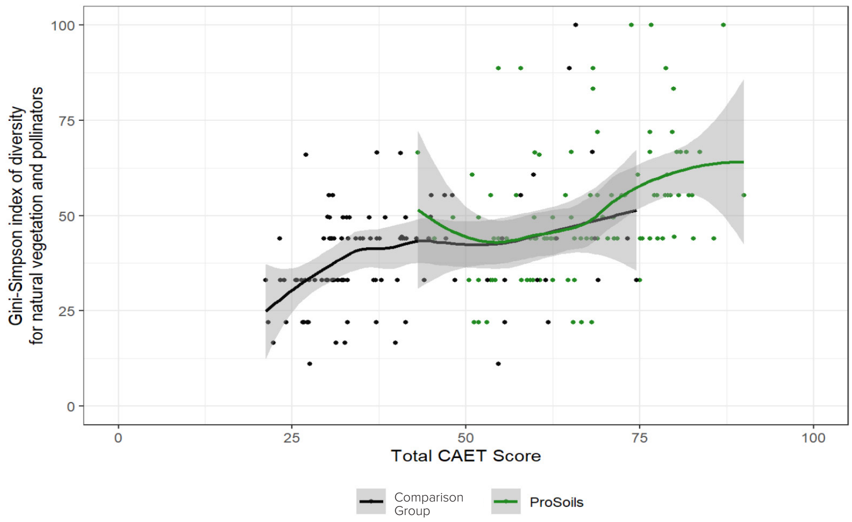


Figure 20. Correlation between CAET score and diversity indices for natural vegetation and pollinators

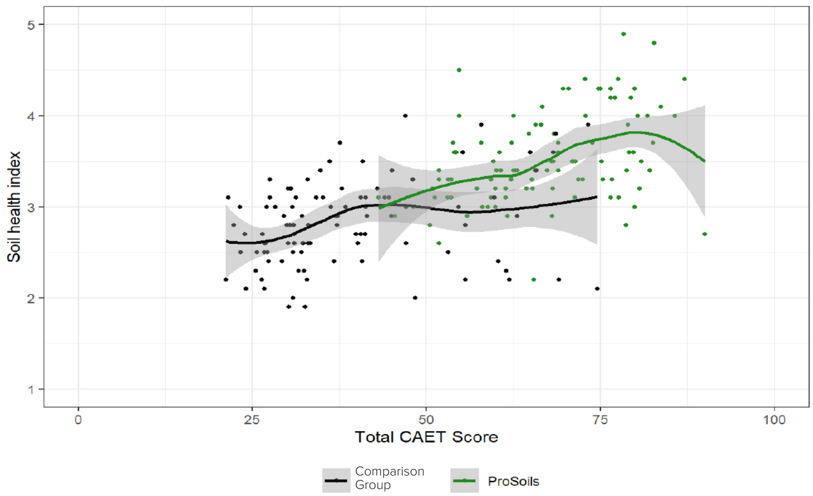


Figure 21. Correlation between CAET score and overall soil health among the ProSoil group and the comparison group based on TAPE data analysis. The soil health indicator is an aggregate indicator encompassing soil structure, soil cover, colour, compaction, soil water retention, erosion, and soil microbial activity.

The soil health indicators showing the strongest correlations with the CAET score are soil cover (r=0.63; Figure 22) and reduced soil erosion (r=0.48; Figure 22). Given that higher levels of agroecological integration are linked to higher scores in diversity indices – particularly for trees, crops and soil microorganisms, which play crucial roles in soil functions, such as enhancing water infiltration and reduction in soil erosion (Astegiano et al. 2024; Ngigi et al. 2021; Teixeira et al. 2021) – advanced agroecological integration is likely to contribute to improved soil health.

Moreover, farms from ProSoil group demonstrated significantly ($p<0.01$) better scores across all biophysical soil health indicators compared with the comparison group. The farms owned by ProSoil group were thus perceived to have superior soil structure, higher water retention capacity, greater humus content, improved soil colour, more active microbial activity (Figure 23), reduced soil compaction, and lower levels of soil erosion.

Contrary to the perceived findings in the TAPE results – which suggested that an increase in the CAET score and participation in ProSoil activities were linked to improved biophysical soil health indicators – soil sample analysis using the Land Degradation Surveillance Framework revealed no significant association between CAET and physiochemical indicators of soil health, such as soil

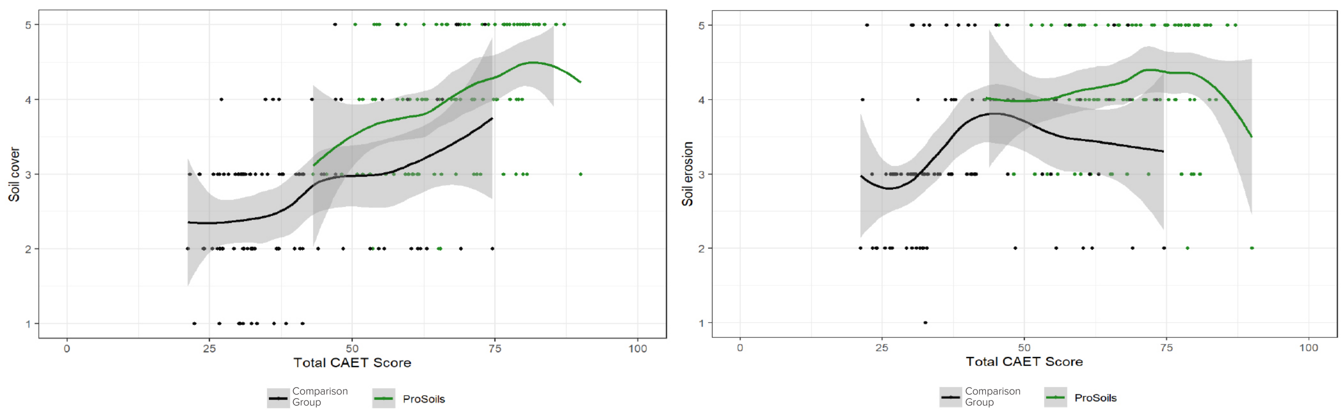


Figure 22. Correlation between CAET score and soil cover (left) and soil erosion (right). A score of 5 on the soil cover graph signifies that over 50% of the soil is either covered by live vegetation or residues. Similarly, a score of 5 on the soil erosion graph indicates the absence of any visible signs of erosion.

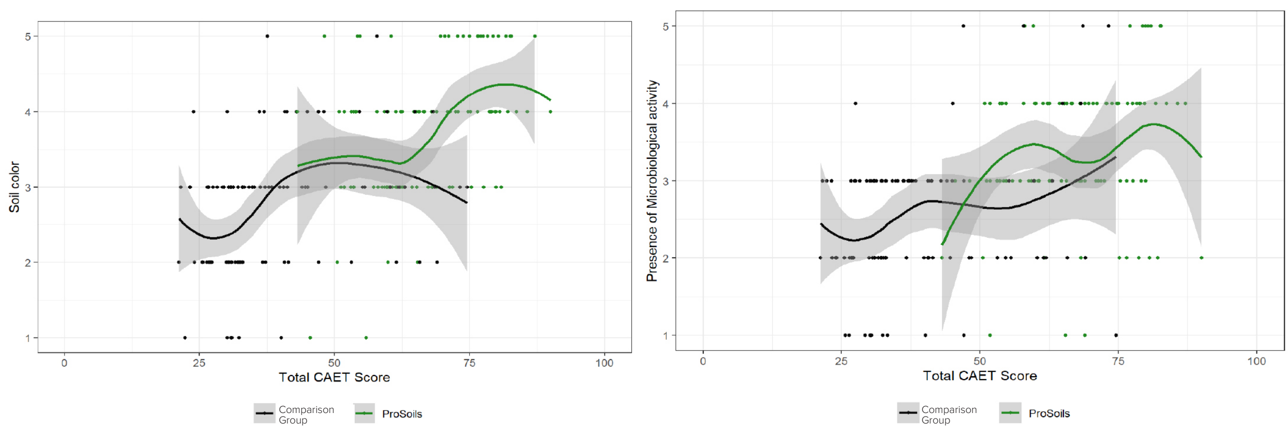


Figure 23. Correlation between CAET score and soil colour (left) and soil microbial activity (right) in ProSoil and the comparison group

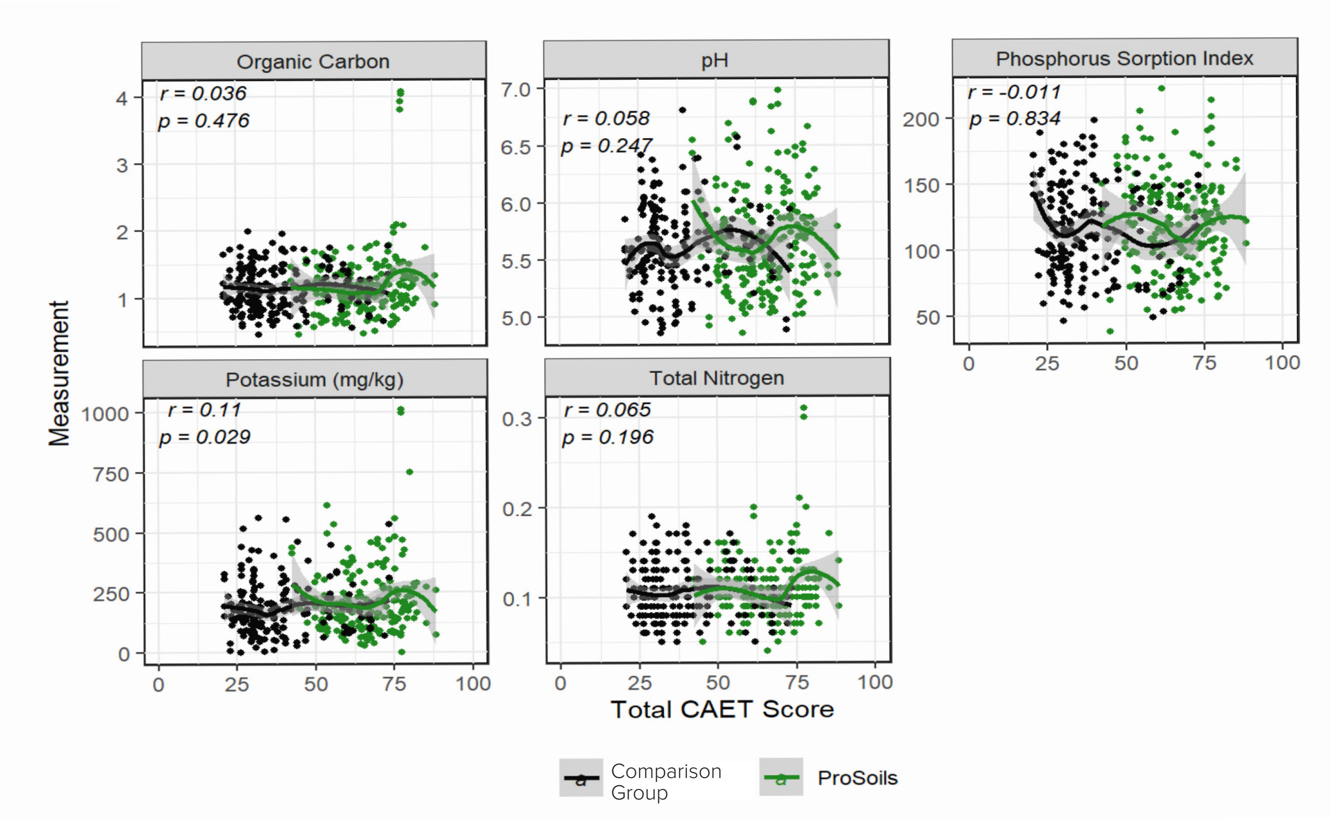


Figure 24. Soil sample analysis results relating CAET score with physiochemical soil health indicators. The soil health indicators assessed using the LDSF method are soil organic carbon (SOC), pH, phosphorus (P), potassium (K) and total nitrogen (TN).

organic carbon (SOC), pH, total nitrogen (TN), and phosphorus (P) (Figure 24). The only soil indicator correlated with the CAET score was potassium (K), which slightly increases ($r=0.1$, $p<0.05$) as the CAET score increases. Furthermore, the implementation of ProSoil activities revealed no discernible difference in any of the five physiochemical soil health indicators (SOC, pH, TN, P and K) when compared with the comparison group. Nonetheless, variations in these elements were evident when examined at county level, with certain counties displaying significantly different levels ($p<0.001$) than others.

This indicates that disparities in physiochemical soil characteristics are more likely due to regional discrepancies rather than the integration of agroecological practices in farming systems. This finding could be explained by the fact that while households from ProSoil group utilize organic soil amendments, the comparison group applies mineral fertilizers, which can enhance soil physiochemical characteristics. Alternatively, soil chemical properties may require more time to be amended, suggesting that the implementation timeframe might not have been sufficient to yield measurable outcomes.

3.3.3 Correlation between CAET score and society and culture indicators

Agroecological approaches focus on promoting equity and social well-being, while improving rural livelihoods (Bisht et al. 2021). To achieve these goals, agroecology's societal and cultural aspects – as integrated into TAPE – emphasize women's empowerment and youth engagement in agriculture.

The findings from this study indicate that the CAET score positively correlates with women's empowerment ($r=0.2$, $p<0.05$). However, there was no evidence ($r=-0.03$, $p>0.5$) linking the CAET score with the overall youth score, which includes youth employment and retention in agricultural practices. This suggests that agroecological advancement is likely to provide the space for social equity by building adaptive capacity for women's involvement in decision making related to natural resource governance, including through leadership opportunities in producer groups (Bisht et al. 2021). Conversely, within the context of the study site, the impact of agroecological integration on youth employment remains unclear.

A comparison between ProSoil and the comparison groups also showed no significant evidence linking youth employment (Figure 25) with agroecological advancement among either ProSoil ($r=0.1$, $p>0.05$) or the comparison groups ($r=0.89$, $p>0.05$). This suggests that the increase in youth employment is likely due to indirect factors other than agroecological transition.

Similarly, youth employment had no significant relationship with any elements of agroecology other than human and social values ($p<0.05$), which is associated with productive labour environments, gender equity, and youth motivation to engage in farming (Table 4). Apparently, production systems that prioritize the integration of social well-being and livelihoods are likely to capture the attention of youth engagement in agriculture.

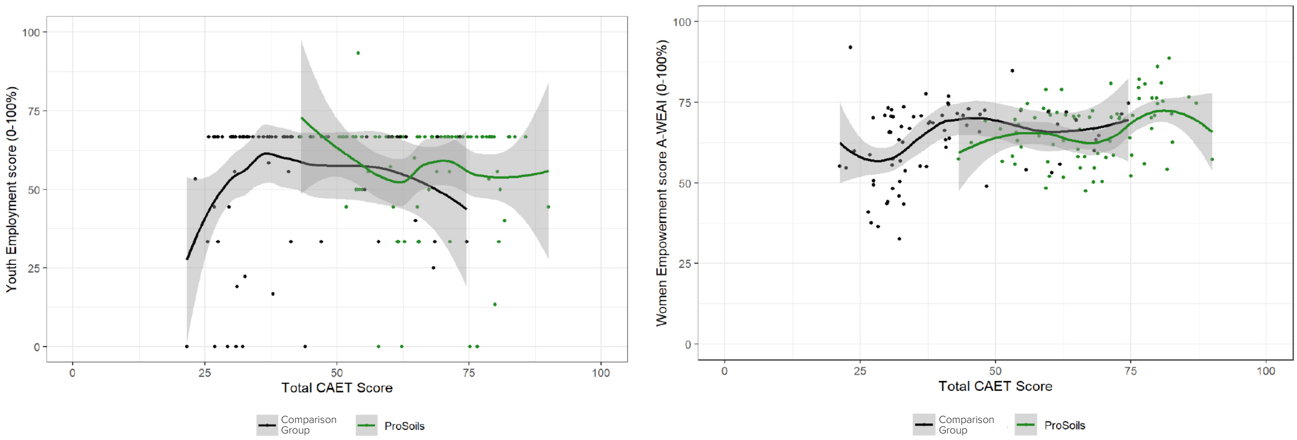


Figure 25. Correlation between CAET score with youth employment score (left) and women's empowerment score (right) within households participating in ProSoil activities and the comparison households

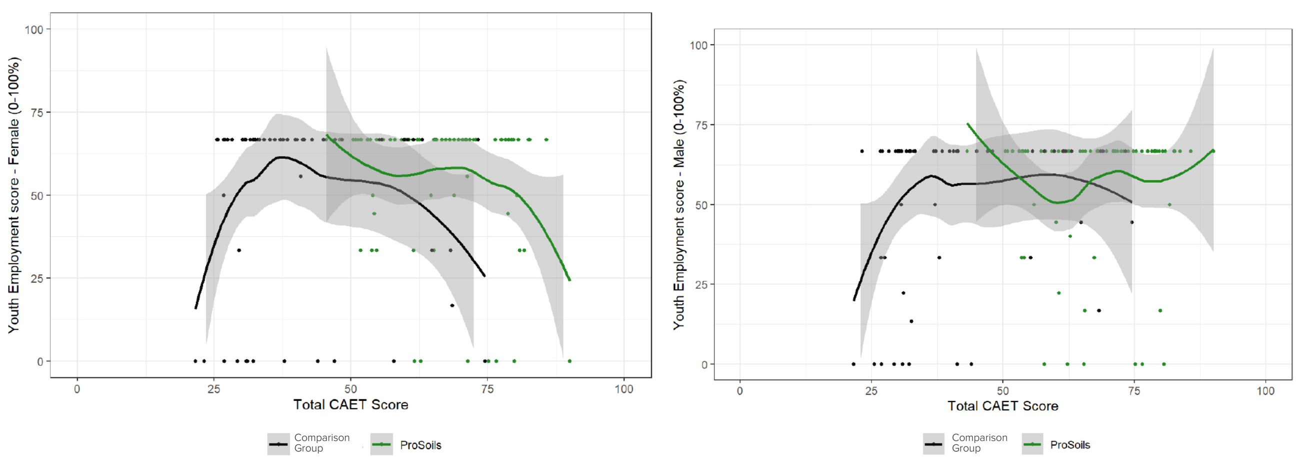


Figure 26. Correlation between CAET score and youth employment score among females (left) and males (right) disaggregated by ProSoil and the comparison group

The implementation of agroecological practices typically demands significant labour inputs and may require a considerable time investment before yielding economic returns (Baum et al. 2023). Coupled with discriminative land tenure rights, especially for females, the proportion of youth employment was found to decline significantly among females compared with their male counterparts (Figure 26).

These attributes are likely to deter youth involvement in employment opportunities related to agroecology, as young individuals often prefer more secure jobs that require less physical labour and yield immediate returns. As a result, they are likely to emigrate in search of alternative income sources with immediate returns, such as motorcycle transport businesses. This assumption is reflected in the generally low and declining proportion of youth engaged in agriculture as the CAET score increases (Figure 27), with ProSoil group experiencing a decline rate in youth engagement seven times (r= -0.181) higher than that of the comparison group (r= - 0.014). Similarly, ProSoil group showed a higher rate of youth emigration (31%) compared with the comparison group (26%).

The above-mentioned findings highlight the necessity to cultivate supportive institutional and labour environments that inspire youth involvement in agroecology as a promising avenue for enhancing

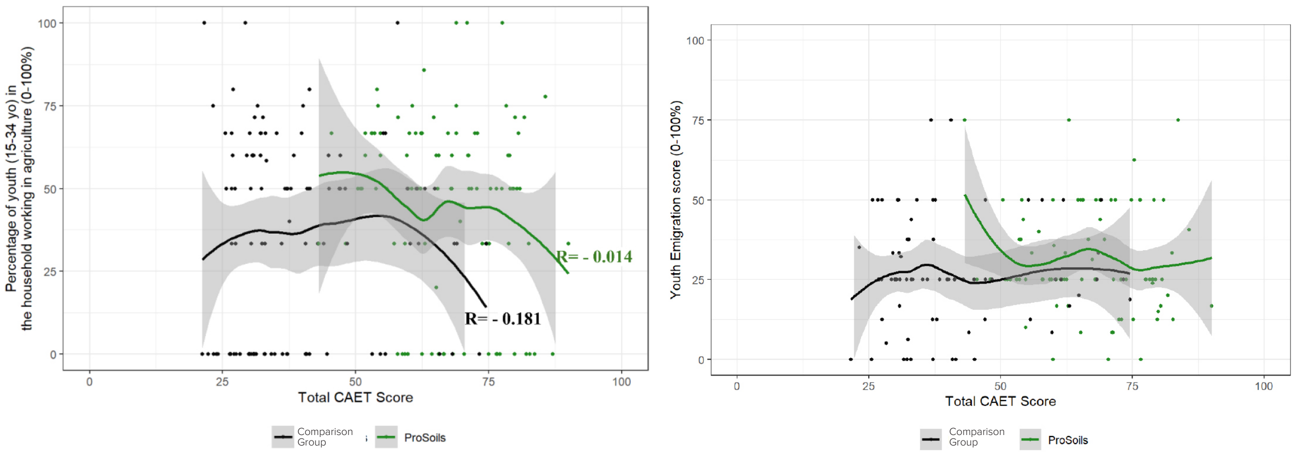


Figure 27. Correlation between CAET score and proportion of youth working in agriculture (left) and youth emigration score (right) disaggregated by ProSoil and comparison group

Table 4. Spearman's rank correlation between youth employment scores and elements of agroecology among the ProSoil and comparison groups

Dimension	**ProSoil group - rho**	**ProSoilgroup - p.value**	**Comparison group - rho**	**Comparison group - p.value**
Total score	-0.096	0.376	0.089	0.437
Diversity	-0.122	0.259	-0.006	0.957
Synergies	-0.039	0.722	0.009	0.934
Efficiency	-0.157	0.147	0.063	0.585
Recycling	-0.147	0.173	0.064	0.579
Resilience	0.075	0.488	-0.025	0.825
Culture and food tradition	-0.042	0.697	-0.013	0.908
Co-creation/sharing of knowledge	-0.141	0.194	-0.019	0.867
Human and social values	0.049	0.65	0.236	0.037*
Circular and solidarity economy	-0.091	0.404	0.026	0.818
Responsible governance	-0.007	0.95	-0.094	0.411

Note: Not significant (ns) p>-0.05; *p<0.05; **p<0.01; ***p<0.001

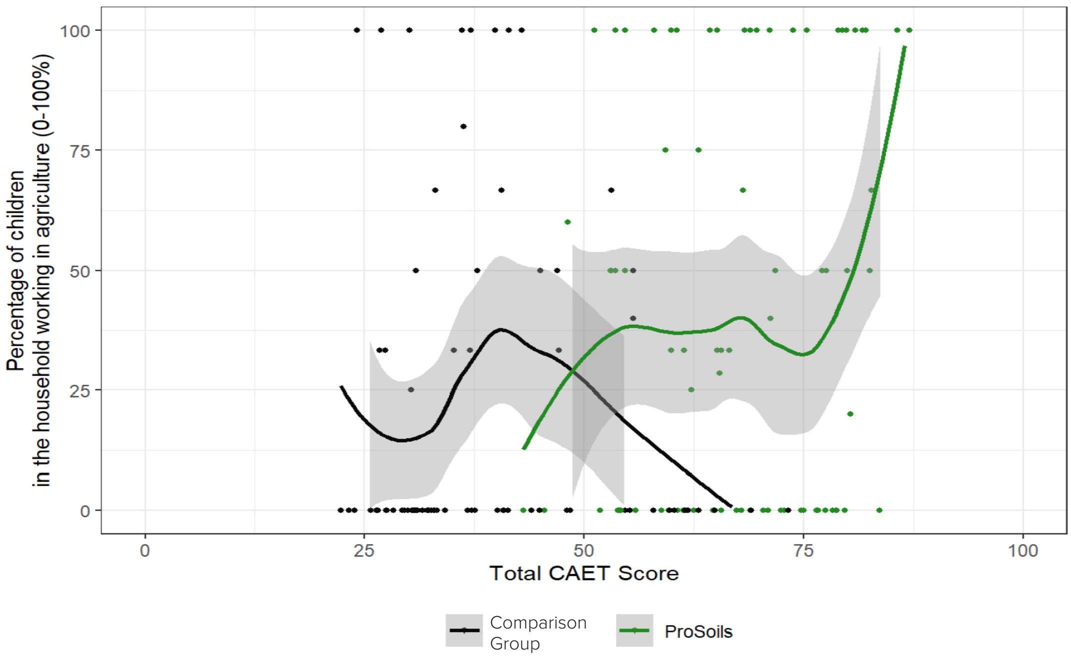


Figure 28. Correlation between CAET score and percentage of children working in agriculture within ProSoil and the comparison group. Children from households participating in ProSoil interventions are more likely to be engaged in agricultural activities especially at CAET scores above 75%.

youth employment within this field. Likewise, tailoring agroecological practices to meet long-term agroecological sustainability while securing young people's immediate economic requirements would be key to fostering youth employment and engagement in agroecology. Bisht et al. (2021) suggest that technological, social and digital innovations that reduce labour constraints in already heavily overworked farmers remain a critical need for encouraging youth involvement in agriculture.

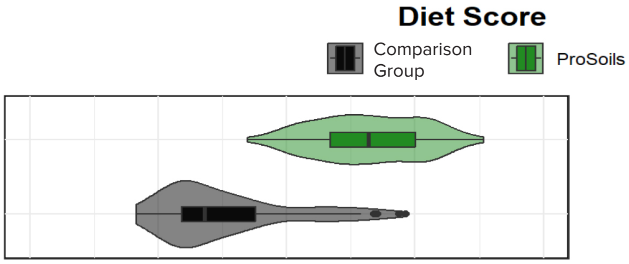
In contrast to the involvement of youth in agriculture, the percentage of children engaged in agriculture rises with the CAET score ($r=0.2$, $p<0.01$). Similarly, among households participating in ProSoil activities, a higher proportion of children (40%) are involved in agriculture compared with the comparison group (20% of children) (Figure 28). This observation may suggest that smallholder farming systems, often reliant on family labour, may inadvertently lead to increased child participation in agricultural activities (Bisht et al. 2021). However, it is important to approach this finding with caution and understand the underlying reasons and motivations for children's involvement in agriculture.

3.3.4 Correlation between CAET score and health and nutrition indicators

Agroecology focuses on promoting equity and social well-being, while improving rural livelihoods by empowering communities to overcome poverty, hunger and malnutrition (Bisht et al. 2021). By fostering access to dietary diversity, through safe and secure methods, agroecological approaches contribute to food security and environmental safety. Our utilization of the TAPE tool assessed how integrating agroecological practices contributes to attaining food security, improving nutrition, and enhancing human well-being.

The findings of this study indicate that an increase in the CAET score is associated with higher diet scores ($r=0.47$, $p<0.001$; Figure 29), suggesting that households with advanced integration of agroecological practices are likely to have more diversified diets, lower food expenditures, and greater food security. Further, households implementing ProSoil activities exhibit a higher mean diet score compared with the comparison group, indicating better food security among ProSoil group.

Additionally, the diet score positively correlates with all elements of agroecology (Figure 30), implying that integrating any of the 10 elements of agroecology is likely to improve a household's diet score. This association between the CAET score and elements of agroecology is stronger among ProSoil group than in the comparison group (Figure 30).



Statistic	Non-ProSoils	ProSoils
Mean	1.9	2.2
Median	1.9	2.3
SD	0.4	0.3
IQR	1.6-2.1	2.0-2.4

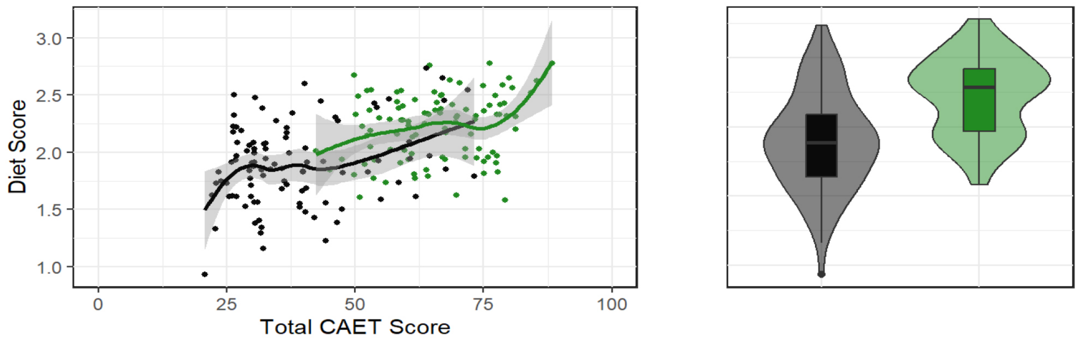


Figure 29. Correlation between CAET score and the overall diet score. Clockwise from top left: i) Violin plot illustrating total CAET scores among ProSoil group and the comparison group, ii) Summary statistics of total diet score, iii) Scatter plot depicting the relationship between diet score and total CAET score, and iv) Violin plot showing the distribution of diet scores among ProSoil and the comparison group.

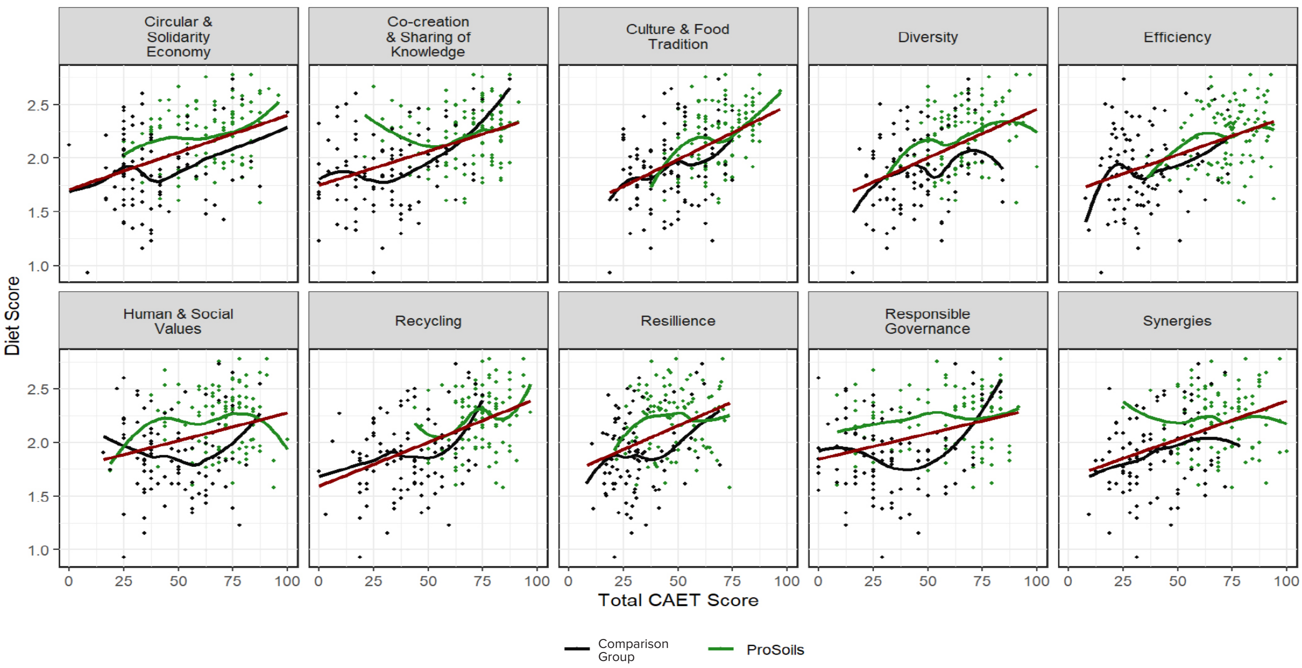
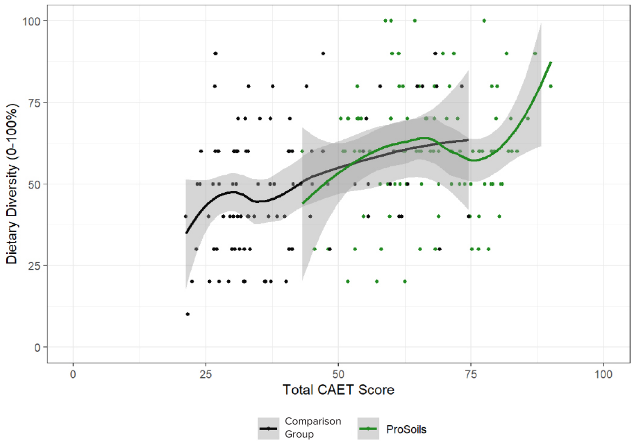


Figure 30. The correlation between total CAET score and overall diet score across the 10 elements of agroecology. The green and black lines represent the moving averages for ProSoil and comparison group, respectively, while the red lines represent the best-fit regression line for the entire dataset. The slope of the red line indicates a positive correlation between diet score and all elements of agroecology.



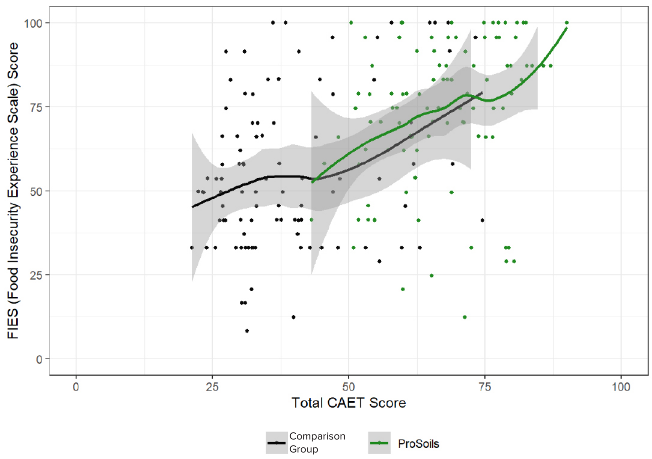


Figure 31. Correlation between CAET score and dietary diversity (left), and food insecurity experience index/FIES (right). A FIES score of 100% indicates households with no food insecurity.

Figure 32. Correlation between CAET score and food expenditure scores disaggregated by ProSoil and comparison groups

The findings of this study indicate that an increase in the CAET score was associated with greater dietary diversity (r=0.34, p<0.001; Figure 31) and improved food security (r=0.47, p<0.001; Figure 31). The CAET score was also linked to increased use of ecological pesticides (r=0.57, p<0.001), leading to a decrease in the area where chemical pesticides were applied (r= -0.24, p<0.001). Thus, farms that integrate agroecological practices will likely have more diverse diets, improved food security, and less exposure to toxic pesticides. However, there was insufficient evidence associating the CAET score with expenditure on food (r=0.09, p<0.22).

Households with more diversified diets were associated with increased farm diversity, synergy, resilience, and co-creation of knowledge. According to previous studies (Mulwa and Visser 2020; Ngigi et al. 2021), farm diversification helps to achieve production stability, to spread household risks, and to foster food security and resilience against natural shocks, such as climate change impacts.

Households participating in ProSoil activities had a significantly higher mean dietary diversity score (60.5%) compared with the comparison group (49.8%, p<0.001). Although food expenditures were not significantly different (p=0.2) between the two groups (Figure 32), the comparison group spent more

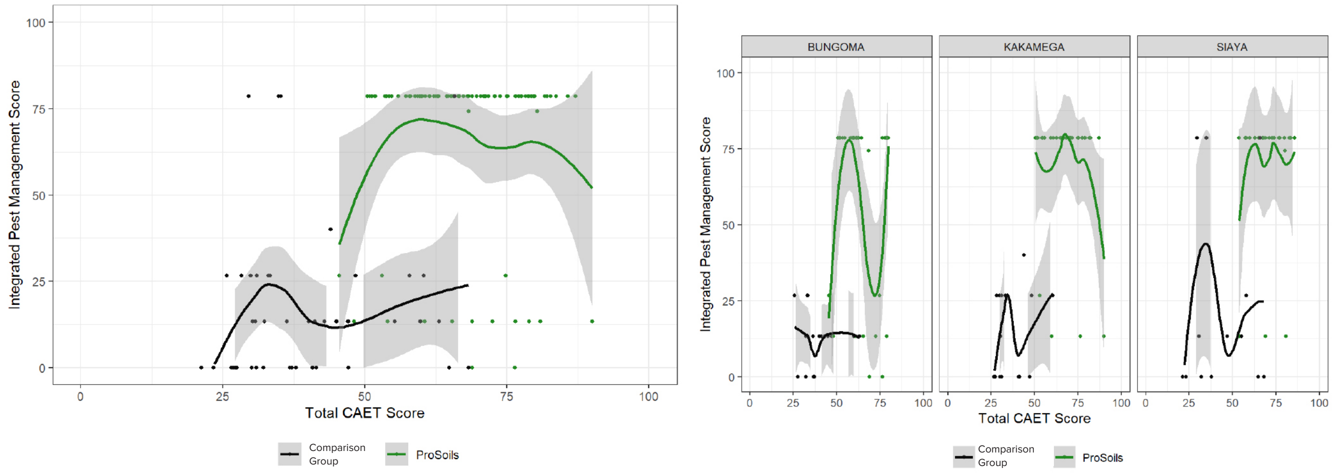


Figure 33. Correlation between CAET score and integrated pest management score disaggregated by ProSoil and the comparison group (left), and across counties (right)

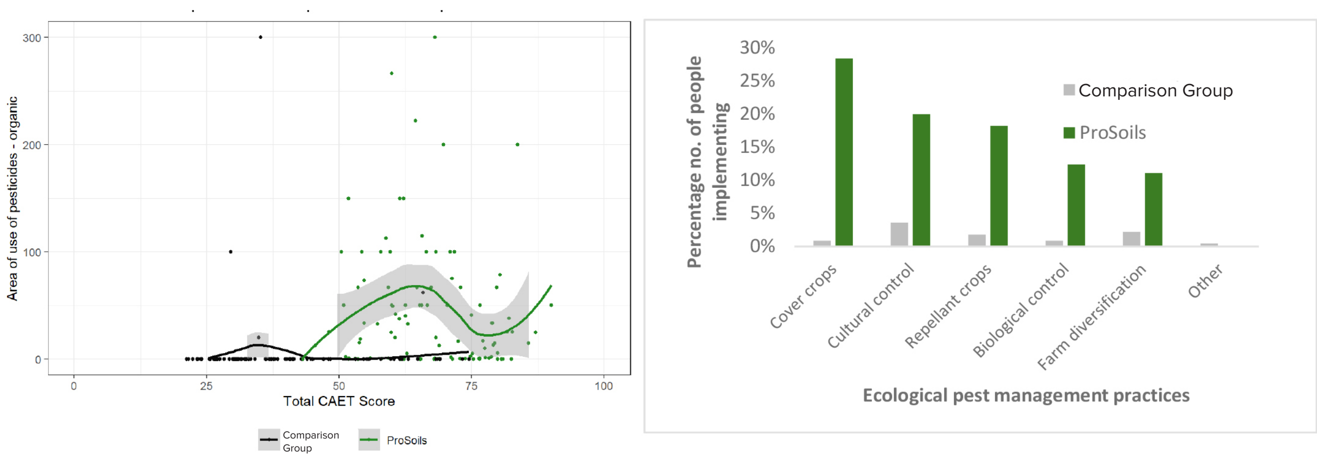


Figure 34. Correlation between CAET score and the area of organic pesticide application (left), and types of ecological pest control adopted by ProSoil and the comparison group (right)

on food (KES 8741) than households from ProSoil group (KES 6953). The high dietary diversity among ProSoil group enhances household food sufficiency, leading to lower food expenditures as their farms transition to more advanced agroecological systems.

The ProSoil group showed significantly higher scores in integrated pest management (IPM) than the comparison group ($p<0.001$), achieving an average score of 67% compared with the comparison group's average score of 16%. This trend was consistent across all three counties (Figure 29) indicating higher adoption of IPM practices among ProSoil group.

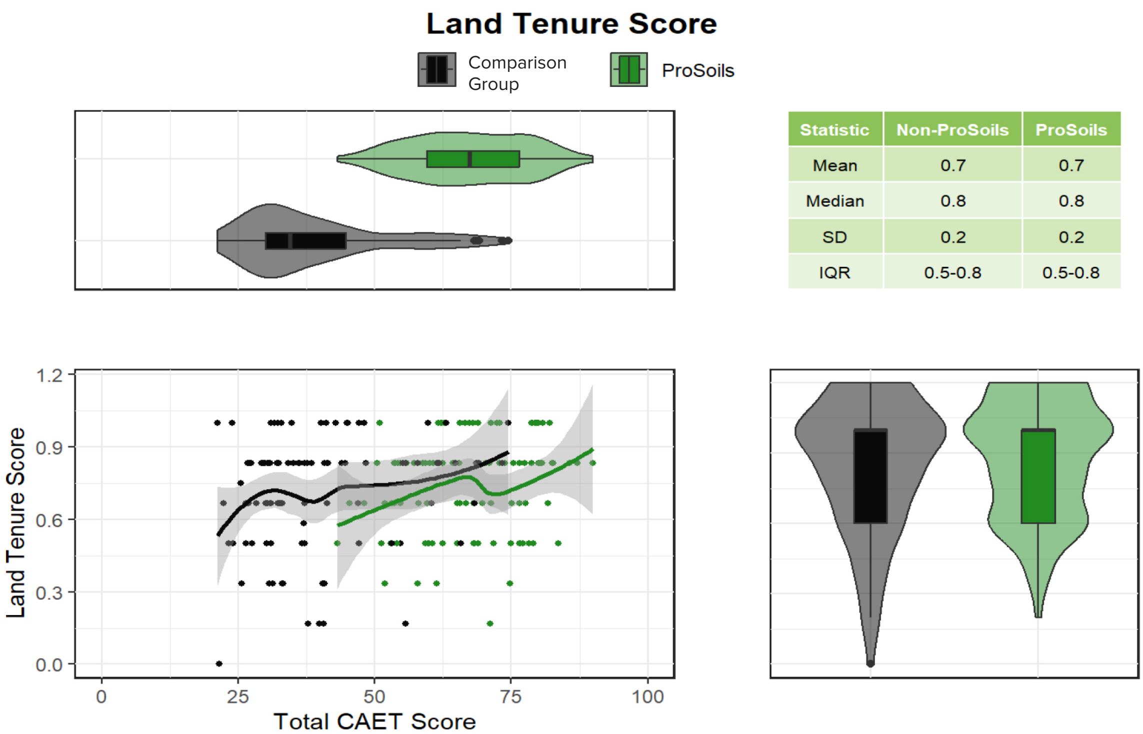
Farmers from ProSoil group make up the majority of those implementing ecological pest management approaches, while the comparison group makes up less than 10% (Figure 34) in the adoption of any of these strategies. This difference in practice resulted in the application of organic pesticides on 45 acres of farms from the ProSoil group compared with just 5 acres within the farms that are not direct beneficiaries of ProSoil activities ($p<0.001$, Figure 34). Of the preferred ecological pest control methods, cultural approaches incorporating the planting of cover crops and repellent crops were the most dominant ones used.

The adoption of ecologically friendly pest management practices potentially reduces exposure to toxic chemicals among ProSoil group. Only 12% of participants from ProSoil group were found to be using used extremely toxic pesticides, compared with more than half (56%) of the comparison group. Despite this exposure to hazardous pesticides, none of the farmers in the comparison group had been informed of the potential adverse impacts of these toxic pesticides. The lack of awareness about ecologically friendly pest management practices and about the potential impacts of hazardous pesticide exposure likely contributes to the comparison group's tendency to use toxic pesticides. Therefore, building capacity and promoting safer alternatives are crucial for fostering behavioural change, particularly among the comparison group.

3.3.5 Correlation between CAET score and land tenure security

TAPE uses land tenure security as the key indicator explaining governance issues in food systems. This is a combination of the reported rights to sell, inherit and bequeath land as well as the current recognition of their land ownership and perceived security. The findings indicate that the CAET score positively correlates with the overall tenure security score. This implies that enhanced tenure security is likely to promote the implementation of agroecological practices. According to Neef et al. (2000), farmers with secure land tenure are more likely to invest in long-term sustainable practices, such as soil conservation, agroforestry, and organic farming. Without assured land ownership or long-term leases, they may be hesitant to implement practices that provide long-term benefits.

3.4 Step 3 of TAPE: Participatory interpretation of results



Statistic	Non-ProSoils	ProSoils
Mean	0.7	0.7
Median	0.8	0.8
SD	0.2	0.2
IQR	0.5-0.8	0.5-0.8

Figure 35. Correlation between CAET score and the overall diet score. Clockwise from top left: i) Violin plot illustrating total CAET scores among ProSoil group and the comparison group, ii) Summary statistics of total land tenure score, iii) Scatter plot depicting the relationship between land tenure score and total CAET score, and iv) Violin plot showing the distribution of land tenure scores among ProSoil and the comparison group.

The participatory interpretation of research findings by relevant stakeholders aimed to provide context to the observed results, to identify gaps and to contribute to informed decision making. This step was conducted through a one-day workshop involving 46 diverse stakeholders, including farmers, civil organizations, as well as representatives from government and private institutions. The workshop's outcome benefitted from the diverse perspectives and experiences of the participants, leading to a more comprehensive understanding of the research output. Additionally, some gaps, potential biases, and recommendations were identified. Key discussions, conclusions and recommendations are highlighted as follows:

Holistic evaluation is critical, yet it might not always be feasible in an objective manner: As this was the first interaction with TAPE for most participants, they acknowledged the strengths and weaknesses of the TAPE tool in holistically assessing the level of agroecological integration and how such integration impacts multidimensional performance. The higher scores observed across all elements of agroecology among ProSoil group revealed the potentiality of such programmes in holistically addressing food system challenges. The added value of a holistic assessment of production systems was particularly marked if one recalls that – unlike the presented TAPE findings where Bungoma County has the lowest level of agroecological integration – a previous GIZ assessment had shown Bungoma outperforming the other counties in adopting agroecological farm practices. This difference was attributed to the methodology: The earlier assessment focused only on three elements of agroecology (recycling, farm diversity and synergy), whereas TAPE's more comprehensive approach encompassed all 10 elements of agroecology. This highlighted that sustainability extends beyond specific farm practices and necessitates a broader scope to achieve a more balanced and sustainable system.

Despite the above-mentioned observations, participants acknowledged that the term "holistic" is relative and suggested that replacing the 10 elements with the 13 principles might provide a more comprehensive assessment. Despite recognizing the importance of a holistic approach, they noted that objectively integrating all elements into a programme might be impractical, as actors tend to prioritize their targeted objectives in response to targeted challenges. For instance, the ProSoil project primarily focused on elements related to agroecological farm practices. Assessing the project against all elements that it did not intentionally target might not accurately reflect its impacts on societal goals. Therefore, participants suggested that sustainable agriculture benefits from diverse contributions, and that collaborative efforts among development organizations working on different, but related, aspects of agroecology could drive the process of achieving a holistic food system.

Upscaling sustainable farming practices is key to agroecological integration: The significant contribution of ProSoil project activities to agroecological integration highlighted a need for the sustained implementation of programmes related to sustainable agriculture. However, the strong association of agroecological integration with small-sized farms was attributed to development programmes focusing primarily on small-scale farms. Despite ProSoil group's proximity to the comparison group, the notable disparity in the level of agroecological integration between the two groups suggested limited knowledge transfer among the participating and non-participating farms. Participants recommended intentional efforts to build the capacity of producers and producer organizations, incorporating farmer-to-farmer knowledge-exchange programmes to enhance ownership, connectivity among producers, and the sustained implementation of agroecological practices on a larger scale beyond the confines of the project.

Agroecological integration impacts multidimensional indicators: Participants collectively agreed on the positive effect of agroecological integration on societal goals, including improved productivity, incomes and wealth creation from farming activities, as well as enhanced agrobiodiversity, soil health and social well-being. The temporary decline in productivity per hectare was attributed to the time required for soil health to improve, and for beneficial ecological interactions to become established. However, as the new practices take root, benefits such as enhanced soil fertility, improved biodiversity, and better water retention contribute to increased productivity over time. Further, during the transition to agroecology, farmers were reported to incur costs for farm inputs, machinery and labour. Despite heavy reliance on household labour, the implementation of agroecological farming practices – such as compost and biopesticide preparation – is time- and labour-intensive, resulting in lower productivity per person among ProSoil group compared with the comparison group.

Regarding the implications of agroecological integration for soil health, participants noted the expected improvements in biophysical characteristics reported in the TAPE analysis. However, the low soil organic carbon (SOC) levels were explained by the fact that building soils takes time, and the period of implementing agroecological practices might have been insufficient to show meaningful results. One participant said it typically takes eight to 10 years for agroecological farm practices to significantly impact SOC. To ensure tangible outcomes in soil health, participants proposed that programmes, like ProSoil, be implemented over longer periods.

Given the diversity of stakeholders, there was an in-depth discussion on the potential of relying solely on organic fertilizer to achieve optimal soil health. Considering the limited access to organic inputs, an integrated approach combining both mineral and organic fertilizers was deemed to offer a win-win solution. This approach would enhance soil health while minimizing potential conflicts with input producers and suppliers.

Youth and children's engagement in agriculture: Participants concurred with findings linking agroecological intensification to a decrease in youth engagement but an increase in children's involvement in agriculture. The discussion on the high rate of youth emigration was deemed crucial in devising strategies to re-engage youths in farming. It was unanimously agreed that youths seek quick and guaranteed results from activities requiring less manual labour, which is often at odds with the labour-intensive agroecological practices that yield benefits over extended periods. This is compounded by tenure insecurity, as youths are uncertain about reaping the rewards of their labour due to land ownership issues. "*Let's make agroecology 'cool' to the youth*," remarked one participant. "*They will engage in anything associated with technology, yields immediate income, and if they are sure of their land tenure security*." Regarding youths' preference for white-collar jobs over farming, one participant clarified, "*Many youths will be willing to get their hands dirty as long as they make money*." Consequently, participants proposed that integrating precision agriculture, information and communications technology, digital marketing technologies, and policies supporting tenure security would be key strategies to attract youths to agriculture.

The high proportion of children from households with advanced agroecological transition and from ProSoil group engaged in agriculture was not viewed as a sign of child labour. Instead, it was largely agreed that children find agroecological innovations promoted by ProSoil – such as the production of vermi juice, biopesticides, composted manure, tree nurseries, and agroforestry – interesting and engaging as experiments. Additionally, the implementation of the Competency-Based Curriculum in schools – which emphasizes practical learning activities, promotes farming practices and fosters future self-reliant young adults – translated to children's interests at home. Further, participants stressed the need to distinguish between light duties and child labour to assess the value of involving children in farming activities. Consequently, the evaluation of actual roles played by children in agriculture, and whether such engagements affect their education time, was recommended. Overall, engaging children in agriculture was considered a positive aspect in fostering their interest and understanding of the value of agriculture during their formative years.

Drivers of agroecological transition: Generally, participants identified key drivers for adopting agroecological farming practices and highlighted the challenges in advancing agroecological transition. A detailed discussion on the role of policies in agroecological transition revealed that, although not explicitly labelled as 'agroecological,' policies addressing specific elements of agroecology have been in place. However, a lack of awareness among relevant actors; poor enforcement; and bureaucratic hurdles in approving and adopting contextualized policies – evidenced by numerous regulations, bills, policies and guidelines remaining in draft form – render these policies ineffective in addressing challenges in food systems.

Inadequate support from the government was mentioned as a key hindrance to agroecological transition. The biased provision of subsidies for mineral fertilizers and ploughing tractors conveyed a skewed message to farmers about the most appropriate methods for achieving sustainability in food systems. These subsidies led to biased stocking by input suppliers and coupled with farmers' limited knowledge about input options, resulted in an increased tendency among farmers to adopt external inputs. Noting the insufficient access to organic inputs at affordable prices, farmers resorted to local production of organic farm inputs, such as fertilizers and pesticides, a labour-intensive venture that inhibits the application of agroecological practices on small-scale farms. This was reflected in the fact that the level of agroecological integration decreased with farm size. In addition to the constraints on organic inputs, participants reported that development agencies that are well-known for promoting agroecological intensification tend to focus more on small-scale farms, leaving out larger farms.
The need to expand agroecological integration beyond the farm level was emphasized. Similarly, integrating sustainable mechanization that aligns with agroecological principles, while alleviating the labour burdens associated with these practices, was proposed as a key strategy for advancing agroecological intensification.

4 Summary of findings, conclusions and recommendations

Within the collaborative Agroecology TPP project, known as Measuring Agroecology and its Performance (MAP), the FAO's Tool for Agroecology Performance Evaluation (TAPE) methodology was integrated with a comprehensive soil sampling and analysis methodology based on the Land Degradation Surveillance Framework (LDSF). This combined approach was implemented in three Kenyan counties, where the GIZ global initiative Soil Protection and Rehabilitation for Food Security (ProSoil) has been working with farmers to advance agricultural productivity and welfare by enhancing soil health and fertility management practices.

The study presents TAPE as a useful tool for assessing the degree of agroecological integration within production systems as well as the contributions of such agroecological integration to multidimensional societal goals. Although the overall level of agroecological integration is still at its incipient stages (CAET=53%), necessitating a need for further advancement, the high CAET scores achieved among the ProSoil group across all elements, compared with the comparison group, demonstrate that project interventions – like ProSoil – focusing on elements of agroecology can significantly contribute to a more holistic and sustainable transformation of food systems. However, despite the holistic approach that integrates multiple elements of agroecology, the low scores on responsible governance among households from the ProSoil group highlight the need for development agencies, like GIZ, and farmer cooperatives to empower farmers to engage in a democratic decision-making process regarding access to and governance of natural resources.

The synergistic interactions observed among all elements of agroecology underscore the importance of considering and integrating all elements in the transition of food systems to achieve sustainability. Given that implementers often prioritize specific elements due to resource constraints, among other reasons, a collaborative approach among actors working on different, but related, elements of agroecology are recommended for a more holistic and sustainable agrifood system. Additionally, adopting interventions that simultaneously address or integrate multiple elements of agroecology would facilitate optimal agroecological transitions. To accelerate agroecological integration across the study area, county governments should establish an umbrella body to coordinate project activities implemented by development agencies and aimed at achieving agroecological transitions. Such collaborations would be significant in scaling up agroecological practices and enhancing the sustainability of farming systems on a broader scale, particularly those elements (i.e., synergy, efficiency, co-creation and sharing of knowledge) that were observed to strongly correlate with overall CAET scores.

The sharp disparity in the overall CAET scores of ProSoil (67%) and the comparison group (38%), despite their spatial proximity, implies limited technological and knowledge transfer between the two groups. This observation highlights an opportunity for development organizations to foster farmer knowledge-exchange programmes involving project beneficiaries and non-beneficiary groups, thereby prompting knowledge transfer and the adoption of sustainable farming approaches beyond the spatial scope defined by projects.

Agroecological advancement is linked to multiple improvements in achieving societal goals. Farms and households with higher levels of agroecological integration are likely to experience improved farm productivity, higher incomes, and increased wealth creation (value added). However, agroecological transitions require greater expenditures on farm inputs, such as fertilizers, pesticides, seeds and machinery. Interestingly, participation in ProSoil activities significantly reduced expenditures on farm inputs, probably due to a reliance on locally available or produced inputs. Nonetheless, the production of organic farm inputs, like composted manure and biopesticides, is labour- and time-intensive, leading to a decline in productivity per person as the CAET score increases. To make agroecology more profitable and attractive, a collective assessment and development of tools and approaches are needed to reduce labour burdens while enhancing productivity.

In terms of the social components of human well-being, agroecological advancement enhances dietary diversity, promotes household food security, reduces food expenses, and empowers women to engage in democratic decision making for agricultural activities. However, youths tend to prioritize immediate financial gains over long-term food sufficiency, a need not adequately met by agroecological integration. This – combined with insecure land tenure rights and uncertainties surrounding agricultural employment – contributes to youth emigration from farming, particularly from labour-intensive agroecological farms that offer benefits only after a long wait. The study found that the proportion of youth engaged in agriculture decreases at a rate seven times higher among ProSoil participating households than the comparison group, indicating that ProSoil activities are not fully appreciated or prioritized by young people. To address this challenge, it is essential to tailor agroecological practices to meet both long-term sustainability goals and the immediate economic needs of youth, fostering their re-engagement in agroecological transitions. The study also recommends integrating youth-friendly and ecologically sound technological advancements, such as information and communication technology (ICT) tools for better farm management. These tools – like mobile apps for monitoring crop health, weather forecasts, and efficient farm planning – can save time and reduce unnecessary labour burdens. Youths are more likely to engage in activities associated with ICT as they find them interesting and more respectable in society. Additionally, securing land tenure through the development and enforcement of supportive policies is recommended to strengthen youths' confidence about benefitting from their efforts while engaging in farming activities.

Beyond the social and economic implications, our findings provide significant evidence of a positive correlation between the CAET score and agrobiodiversity, as indicated by diversity indices of crops, animals, natural vegetation, and pollinators. Additionally, farms with more advanced agroecological intensification tend to exhibit improved biophysical soil health indicators, such as better soil structure, soil colour, soil cover, microbial activity, enhanced soil water retention, and reduced erosion. Notably, farms where ProSoil activities are actively implemented were more likely to show improved soil health indicators compared with the comparison group. However, the study found no association between the CAET score, and physiochemical soil health indicators assessed through the LDSF methodology. Similarly, there was no significant difference between ProSoil and the comparison groups regarding indicators assessed through the LDSF methodology (soil organic carbon, pH, total nitrogen, and phosphorus).

Interestingly, differences in these indicators were more closely linked to territorial differences rather than the implementation of agroecological farming practices. Thus, soil management interventions should tailor agroecological interventions to account for territorial differences in soil health indicators to ensure more effective and context-specific strategies rather than addressing soil health at a farm level. The disparity observed in soil assessment outcomes from the TAPE and LDSF methods indicates a delay in the transition to agroecology and the realization of enhanced biophysical soil qualities. This highlights the necessity to integrate farmer-centred evaluations with laboratory analyses to achieve a thorough assessment of agroecological performance. Similarly, the absence of variation in physiochemical characteristics between the two groups stemmed from ProSoil group's use of organic soil amendments, while the comparison group employed mineral fertilizers – both approaches contribute to overall soil health improvement. Rather than recommending an immediate shift to exclusively organic inputs, it was suggested that agroecological transitions should adopt an integrated approach combining mineral and organic fertilizers. This strategy would enhance soil health while mitigating potential conflicts with input producers and suppliers.

References

Amoak D, Luginaah I, McBean G. 2022. Climate change, food security, and health: Harnessing agroecology to build climate-resilient communities. *Sustainability* 14(21):13954. https://doi.org/10.3390/su142113954

Astegiano J, Carbone L, Zamudio F, Tavella J, Ashworth L, Aguilar R, Beccacece HM, Mulieri PR, Nolasco M, Torretta JP, Calviño A. 2024. Diversifying agroecological systems: Plant-pollinator network organisation and landscape heterogeneity matter. *Agriculture, Ecosystems & Environment* 361. https://doi.org/10.1016/j.agee.2023.108816

Baum D and Mechsner S. 2023. *Jobs perspectives in agroecology: More employment, better income*. https://www.giz.de/en/downloads/giz2023-en-policy-brief-beschaeftigung-agrar.pdf

Bisht IS, Rana JC, Jones S, Estrada-Carmona N, Yadav R. 2021. Agroecological approach to farming for sustainable development: The Indian scenario. *In* Hufnagel L. ed. *Biodiversity of Ecosystems*. https://doi.org/10.5772/INTECHOPEN.100281

County Government of Kakamega. 2023. *Kakamega County Integrated Development Plan 2023-2027*. https://www.kakamega.go.ke/kakamega-county-integrated-development-plan-2023-2027/. Accessed in November 2023.

County Government of Siaya. 2023. *Siaya County Integrated Development Plan 2023-2027*. https://repository.kippra.or.ke/handle/123456789/4558. Accessed in November 2023.

Jolliffe DM, Mahler DG, Lakner C, Atamanov A, Tetteh-Baah SK. 2022. *Assessing the impact of the 2017 PPPs on the international poverty line and global poverty*. Policy Research Working Paper. WPS 9941. Washington DC: World Bank Group. https://documents.worldbank.org/curated/en/353811645450974574/Assessing-the-Impact-of-the-2017-PPPs-on-the-International-Poverty-Line-and-Global-Poverty

FAO (Food and Agriculture Organization of the United Nations). 2018. *The 10 elements of agroecology: Guiding the transition to sustainable food and agricultural systems.* Rome: FAO. https://www.fao.org/3/i9037en/i9037en.pdf

Fernandez M and Ernesto Méndez V. 2018. Agroecology and sustainable food systems subsistence under the canopy: Agrobiodiversity's contributions to food and nutrition security amongst coffee communities in Chiapas, Mexico. *Agroecology and Sustainable Food Systems* 43(5):579-601. https://doi.org/10.1080/21683565.2018.1530326

Geck MS, Crossland M, Lamanna C. 2023. Measuring agroecology and its performance: An overview and critical discussion of existing tools and approaches. *Outlook on Agriculture* 52(3):349–359. https://doi.org/10.1177/00307270231196309

GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit). 2020. *ProSilience: Enhancing soils and agroecology for resilient agri-food systems in Sub-Saharan Africa*. https://capacity4dev.europa.eu/projects/desira/info/prosilience_en. Accessed in February 2024.

GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit). 2021. *Soil protection and rehabilitation for food security*. Berlin: BMZ. https://www.giz.de/ en/downloads/giz2023-en-prosoil-bmz.pdf

Hasell J. 2024. From $1.90 to $2.15 a day: The updated international poverty line. *Our World in Data*. https://ourworldindata.org/from-1-90-to-2-15-a-day-the-updated-international-poverty-line. Accessed in April 2023.

HLPE (High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security). 2019. *Agroecological and other innovative approaches for sustainable agriculture and food systems that enhance food security and nutrition.* HLPE Report 14. Rome: FAO. https://www.fao.org/3/ca5602en/ca5602en.pdf

KNBS (Kenya National Bureau of Statistics). 2019. *2019 Kenya population and housing census: Counting our people for sustainable development and devolution of services*. Nairobi, Kenya:

KNBS. https://new.knbs.or.ke/wp-content/uploads/2023/09/2019-Kenya-population-and-Housing-Census-Volume-3-Distribution-of-Population-by-Age-and-Sex.pdf

Liebert J, Benner R, Bezner Kerr R, Björkman T, De Master KT, Gennet S, Gómez MI, Hart AK, Kremen C, Power AG et al. 2022. Farm size affects the use of agroecological practices on organic farms in the United States. *Nature Plants* 8:897–905. https://doi.org/10.1038/s41477-022-01191-1

Lucantoni D, Thulo M, Makhoebe LM, Mottet A, Bicksler A, Sy MR. 2022. *Report on the use of the Tool for Agroecology Performance Evaluation (TAPE) in Lesotho in the context of the Restoration of Landscape and Livelihoods Project (ROLL): Results and analysis*. Rome: FAO. https://www.fao.org/agroecology/database/detail/en/c/1508059/

Mottet A, Bicksler A, Lucantoni D, De Rosa F, Scherf B, Scopel E, López-Ridaura S, Gemmil-Herren B, Bezner Kerr R, Sourisseau JM et al. 2020. Assessing transitions to sustainable agricultural and food systems: A Tool for Agroecology Performance Evaluation (TAPE). *Frontiers in Sustainable Food Systems* 4. https://doi.org/10.3389/fsufs.2020.579154

Mulwa CK and Visser M. 2020. Farm diversification as an adaptation strategy to climatic shocks and implications for food security in northern Namibia. *World Development* 129. https://doi.org/10.1016/j.worlddev.2020.104906

Neef A, Sangkapitux C, Kirchmann K. 2000. *Does land tenure security enhance sustainable land management? Evidence from mountainous regions of Thailand and Vietnam*. https://www.researchgate.net/publication/268395713

Ngigi MW, Mueller U, Birner R. 2021. Livestock diversification for improved resilience and welfare outcomes under climate risks in Kenya. *The European Journal Development Research* 33:1625–1648. https://doi.org/10.1057/s41287-020-00308-6

Ong TWY and Liao W. 2020. Agroecological transitions: A mathematical perspective on a transdisciplinary problem. In *Frontiers in Sustainable Food Systems* 4:91. https://doi.org/10.3389/fsufs.2020.00091

Sachet E, Mertz O, Le Coq J-F, Cruz-Garcia GS, Francesconi W, Bonin M, Quintero M. 2021. Agroecological transitions: A systematic review of research approaches and prospects for participatory action methods. *Frontiers in Sustainable Food Systems* 5:709401. https://doi.org/10.3389/FSUFS.2021.709401

Teixeira HM, Bianchi FJJA, Cardoso IM, Tittonell P, Peña-Claros M. 2021. Impact of agroecological management on plant diversity and soil-based ecosystem services in pasture and coffee systems in the Atlantic forest of Brazil. *Agriculture, Ecosystems & Environment* 305. https://doi.org/10.1016/j.agee.2020.107171

Villavicencio-Valdez GV, Jacobi J, Schneider M, Altieri MA, Suzán-Azpiri H. 2023. Urban agroecology enhances agrobiodiversity and resilient, biocultural food systems. The case of the semi-dryland and medium-sized Querétaro City, Mexico. *Frontiers in Sustainable Food Systems* 7. https://doi.org/10.3389/FSUFS.2023.1066428

Wezel A, Herren BG, Kerr RB, Barrios E, Gonçalves ALR, Sinclair F. 2020. Agroecological principles and elements and their implications for transitioning to sustainable food systems. A review. *Agronomy for Sustainable Development* 40(6), Article No. 40. https://doi.org/10.1007/s13593-020-00646-z

Annexes

Annex 1. Key informant interview for Step 0: A structured approach to understanding the context of TAPE assessments

This is a description of an approach developed for the GIZ MAP Project's implementation of TAPE. The following is a recommendation based on the goals of Step 0 defined by FAO and a careful exploration of the information required to meet those goals.

Step 0 – Introduction to the section

The process identifies three levels of information that are required to fully understand the AE context in which surveyed farms exist:

1. Any grouping of farms that is defined by the study. (In the case of ProSoil, this includes two groups: a ProSoil group and a comparison group)
2. The geographical site
3. Agricultural systems that exist within a site

Grouping of farms

For this survey, this section asks for a description of the two groups: the group of farms involved in ProSoil activities, and the comparison group of farms that are not involved.

More generally, we suggest this would be a section where implementing teams can define their own groups based on their study design.

We also provide space to upload documentation explaining the sampling process.

Geographical site

An implementing team may define a single site as the location for the survey. This option is available if the entire survey is conducted in an area that is roughly homogeneous in terms of Agroecological Zone.

If the survey spans across different locations that are quite different in terms of Agroecological Zone, then the implementing team should define multiple sites.

For each site, the team is asked for the location (described using the common administrative structure for the country), and to identify the dominant Agroecological Zone, as defined by FAO (link here).

Agricultural system

Within each site, there are one or more high-level agricultural systems. While a single farm can be considered a "system" in itself, this section seeks to define the properties of higher-level systems that many farms operate within. The intention is to provide a baseline and enable the comparison of farms at a local level using Steps 1 and 2, rather than comparing farms from very different contexts.

An implementing team is asked to define one or more "agricultural systems" per site. Some guidance is given on how to identify whether you have one or many systems, and then a series of questions are asked to help understand the context:

1. Enter a short, descriptive name for the system.
2. Describe the productive activities relating to crops, livestock, agroforestry, forests and fishing in this system.
3. Describe the current status of biophysical resources used in farming and the trends that have affected them in the recent past.
4. What are the demographic characteristics of the farmers in this system?
5. What are the main problems affecting farming in the system?
6. What are the market conditions affecting farmers? (Both barriers and enablers)
7. Are there any policies that have an important effect on farmers within the system at this point in time?
8. Are there any other incentives or barriers that affect the behaviour of farmers?
9. Are there economic aspects that affect production and productivity in the system?
10. How is climate change affecting farming within the system?
11. Based on all these factors, please provide your own analysis of the level at which the system is performing.

Each question includes a large free-text entry and a space to upload related documentation.

Annex 2. Key indicators used in assessing agroecological performance.

Group	Subgroup	Column name	Indicator name	Unit of measurement	Description
Health and nutrition	Dietary diversity and food security	Dietary diversity	Dietary diversity	Percentage	This indicator measures how diverse the respondent's diet is based on whether they have consumed a particular food group within the last 24 hours, including meats, eggs, dairy, vitamin A-rich fruits and vegetables, other fruits, other vegetables, grains, pulses and nuts. The higher the score, the more diverse the respondent's diet.
Health and nutrition	Dietary diversity and food security	FIES_score	Food insecurity experience scale	Percentage	This indicator measures the level of food insecurity based on a combination of how often in the past 12 months they have experienced various signs of food issues, including: (i) worried that they would have no food, (ii) were unable to eat healthy foods, (iii) skipped meals, (iv) ate smaller meals, (v) went hungry, and (vi) went whole days without food. The higher the score, the more secure their food situation.
Health and nutrition	Dietary diversity and food security	food_exp_capita	Food expenditure per capita	Local currency	This indicator shows how much money the household has spent on food in the past 12 months, per person within the family. This is shown in local currency.
Health and nutrition	Exposure to pesticides	cpused	Quantity of chemical pesticide used	Litres	This is a measure of how much chemical pesticide the respondent has used on their farmland. Measured in litres.

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Group	Subgroup	Column name	Indicator name	Unit of measurement	Description
Health and nutrition	Exposure to pesticides	coused	Quantity of organic pesticide used	Litres	This is a measure of how much organic pesticide the respondent has used on their farmland. Measured in litres.
Health and nutrition	Exposure to pesticides	ctox1	Use of extremely toxic chemical pesticides	Yes/No	This is a simple yes/no measure as to whether the respondent has reported the use of extremely toxic chemical pesticides.
Health and nutrition	Exposure to pesticides	ctox2	Use of moderately toxic chemical pesticides	Yes/No	This is a simple yes/no measure as to whether the respondent has reported the use of moderately toxic chemical pesticides.
Health and nutrition	Exposure to pesticides	otox1	Use of extremely toxic organic pesticides	Yes/No	This is a simple yes/no measure as to whether the respondent has reported the use of extremely toxic organic pesticides.
Health and nutrition	Exposure to pesticides	otox2	Use of moderately toxic organic pesticides	Yes/No	This is a simple yes/no measure as to whether the respondent has reported the use of moderately toxic organic pesticides.
Health and nutrition	Exposure to pesticides	cpused_ha	Area on which chemical pesticides were used	Hectares	The size of the area on which the respondents used chemical pesticides, measured in hectares.
Health and nutrition	Exposure to pesticides	coused_ha	Area on which organic pesticides were used	Hectares	The size of the area on which the respondents used organic pesticides, measured in hectares.
Health and nutrition	Exposure to pesticides	mitigation_num	Number of mitigation strategies during the application of pesticides	Count	The number of mitigation strategies used in applying pesticides from the following options: - Mask - Body protection - Special protection for women and children - Visible signs of danger after spraying - Community is informed of the danger - Secure disposal of empty containers - Other

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Annex 2. Continued

Group	Subgroup	Column name	Indicator name	Unit of measurement	Description
Health and nutrition	Exposure to pesticides	ecoman_num	Number of ecological pest management methods used	Count	The number of ecological pesticide management methods used from the following options: - Cultural control - Plantation of natural repelling plants - Use of cover crops - Favour the reproduction of beneficial organisms - Favour biodiversity and spatial diversity within the agroecosystem - Other
Health and nutrition	Exposure to pesticides	pest_score	Integrated pest management score	Percentage	A combination of scores based upon the total use of pesticide, their toxicity, the use of mitigation strategies, and ecological pest management methods. The higher the score, the more ecological the farm is in managing pests.
Environment	Agrobiodiversity	GSIndex_crops	Gini-Simpson index of diversity for crops	Percentage	0 means no diversity (monoculture), 1 means infinite diversity
Environment	Agrobiodiversity	GSIndex_animals	Gini-Simpson index of diversity for animals	Percentage	0 means no diversity (only 1 species), 1 means infinite diversity

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Annex 2. Continued

Group	Subgroup	Column name	Indicator name	Unit of measurement	Description
Environment	Agrobiodiversity	GSI_other	Index of diversity for natural vegetation and pollinators	percentage	Average of beekeeping, natural vegetation and pollinators where *Beekeeping* No 0 Yes, wild 0.5 Yes, raised 1 *Productive area covered by natural or diverse vegetation* Absent 0 Small 0.25 Medium 0.5 Significant 0.75 Abundant 1 *Presence of pollinators and beneficial animals* Absent 0 Little 0.33 Significant 0.66 Abundant 1
Environment	Agrobiodiversity	num_crops_c1	Number of species and varieties of crop	count	Total number of species and varieties of crops grown on the farm
Environment	Agrobiodiversity	num_animals_a1	Number of species and breeds of animals	count	Total number of species and varieties of livestock kept on the farm
Environment	Agrobiodiversity	total_lsu	Total Livestock in LSU	lsu	Total number of livestock owned expressed as Livestock Units, a conversion to account for the relative nutritional and feed requirements of different types of livestock. For reference, 1 LSU is considered equivalent to 1 adult dairy cow. The total number of livestock for a particular species is multiplied by a corresponding weight.

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Annex 2. Continued

Group	Subgroup	Column name	Indicator name	Unit of measurement	Description
Environment	Soil Health	structure	Soil Structure	Likert (1 - 5)	Enumerators assessed the soil structure according to the following 5-point scale 1 Loose, powdery soil without visible aggregates 2 3 Few aggregates that break with little pressure 4 5 Well-formed aggregates – difficult to break
Environment	Soil Health	compaction	Soil Compaction	Likert (1 - 5)	Enumerators assessed the soil compaction according to the following 5-point scale 1 Compacted soil, flag bends readily 2 3 Thin compacted layer, some restrictions to a penetrating wire 4 5 No compaction, flag can penetrate all the way into the soil
Environment	Soil Health	depth	Soil Depth	Likert (1 - 5)	Enumerators assessed the soil depth according to the following 5-point scale 1 Thin soil > 1 foot until you hit rock or there is exposed rock on the soil surface 2 3 Shallow to moderate soil – less than 3 feet (1 metre) until you reach bedrock 4 5 Deep soil, more than 3 feet deep

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Annex 2. Continued

Group	Subgroup	Column name	Indicator name	Unit of measurement	Description
Environment	Soil Health	residues	Status of Residues	Likert (1 - 5)	Enumerators assessed the status of residues on the soil according to the following 5-point scale 1 Organic residues are applied but decomposition is very slow, more than 1 year 2 3 Residues are visible they are slowly decomposing during the season 4 5 Residues are quickly decomposed, and we can see various stages of decomposition
Environment	Soil Health	color	Color, odour, and organic matter	Likert (1 - 5)	Enumerators assessed the colour, odour and organic matter of the soil according to the following 5-point scale 1 Pale and no presence of humus 2 3 Light brown, odourless, and some presence of humus 4 5 Dark brown, fresh odour, and abundant humus
Environment	Soil Health	water_ret	Water retention (moisture level after irrigation or rain)	Likert (1 - 5)	Enumerators assessed the water retention of the soil according to the following 5-point scale 1 Dry soil, does not hold water 2 3 Limited moisture level available for short time 4 5 Reasonable moisture level for a reasonable period of time

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Annex 2. Continued

Group	Subgroup	Column name	Indicator name	Unit of measurement	Description
Environment	Soil Health	cover	Soil cover	Likert (1 - 5)	Enumerators assessed the soil cover according to the following 5-point scale 1 Bare soil 2 3 Less than 50% soil covered by residues or live cover 4 5 More than 50% soil covered by residues or live cover
Environment	Soil Health	erosion	Erosion	Likert (1 - 5)	Enumerators assessed the soil erosion according to the following 5-point scale 1 Severe erosion, presence of gullies 2 3 Evident, but low erosion signs (e.g. rill/sheet erosion) 4 5 No visible signs of erosion
Environment	Soil health	Invertebrates	Presence of invertebrates	Likert (1–5)	Enumerators assessed the presence of invertebrates in the soil according to the following five-point scale: 1 No signs of invertebrate presence or activity 2 3 A few earthworms and arthropods present 4 5 Abundant presence of invertebrate organisms

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Annex 2. Continued

Group	Subgroup	Column name	Indicator name	Unit of measurement	Description
Environment	Soil health	Microbio	Microbiological activity	Likert (1–5)	Enumerators assessed the microbiological activity in the soil according to the following five-point scale: 1 Very little effervescence after application of water peroxide to the topsoil 2 3 Light to medium effervescence 4 5 Abundant – longer effervescence period
Environment	Soil health	soil_health	Soil Health Index	Average	This index expresses the average of each of the above-mentioned soil health indicators.
Social	Women's empowerment	AWEAI	Women's empowerment score A-WEAI (Abbreviated Women's Empowerment in Agriculture Index)	Percentage	An index measuring the empowerment of women within the household according to their involvement in the following dimensions: Productive decision making; decisions on income and assets; leadership; time use; and access to credit
Social	Women's empowerment	GPI	Gender Parity Index	Ratio	Ratio of the women's empowerment score vs men's score on the same dimensions. A score of 100 indicates equal parity between men and women in the household. Anything below 100 suggests the women in the household are less empowered than the men. A score above 100 indicates the women in the household have more power than the men.
Social	Women's empowerment	pct_fadult_ag	Percentage of adult women (15+) working in agriculture	Percentage	The percentage of adult women aged 15 and above within the household who are currently working in agriculture

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Annex 2. Continued

Group	Subgroup	Column name	Indicator name	Unit of measurement	Description
Social	Youth empowerment	youth_employ	Youth employment score	Percentage	Sum of: % of young people working in the agricultural production of the system assessed*1 % of young people in education or training*1 % of young people working outside but currently living in the system assessed*0.5 % of young people not in education, nor working in agriculture nor in other activities*0 % of young people who already left the community for lack of opportunities*0
Social	Youth empowerment	youth_emigr	Youth Emigration Score	Percentage	Sum of: % of young people who want to continue the agricultural activity of their parents*1 % of young people who would emigrate, if they had the chance*0.5 % of young people who already left the community for lack of opportunities*0 * The asterisks denote the weighting applied to the respective percentages: *1 means it is multiplied by 1, *0.5 means it is multiplied by 0.5, and *0 means this group is multiplied by 0 and does not contribute to the final score.
Social	Youth empowerment	youth_score	Youth score	Percentage	Average of youth employment and youth emigration score
Social	Youth empowerment	pct_youth_ag	Percentage of young adults (15-34) working in agriculture	Percentage	The percentage of young adults (15-34) within the household who are currently working in agriculture
Social	Others	pct_ag_children	Percentage of children (<15) working in agriculture	Percentage	The percentage of children aged under 15 within the household who are currently working in agriculture

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Annex 2. Continued

Group	Subgroup	Column name	Indicator name	Unit of measurement	Description
Social	Others	pct_family_ag	Percentage of the household working in agriculture	Percentage	The percentage of the whole household who are currently working in agriculture
Economy	Productivity	crop_prodval	Value of crops produced	Local currency	Total value of the farm's crop production output in local currency
Economy	Productivity	cfp_prodval	Value of crop and forestry products produced	Local currency	Total value of the crop and forestry-based products produced by the farm (such as alcohol, coal, bread, juice etc.), including in local currency
Economy	Productivity	anim_prodval	Value of livestock	Local currency	Total value of the livestock on the farm in local currency
Economy	Productivity	anpr_prodval	Value of animal products produced	Local currency	Total value of animal-based products produced by the farm, including meats, fats, dairy products, fabrics and skins etc. in local currency
Economy	Productivity	total_output	Monetary value of agropastoral production	Local currency	Total value of farm outputs (crops, animals, crop and forestry products, animal products) in local currency
Economy	Productivity	tot_productivity_pers	Gross value of agricultural production (per person)	Local currency	Total productivity per person – crops, animals, crop and forestry products, animal products
Economy	Productivity	tot_productivity_ha	Gross value of agricultural production (per ha)	Local currency	Total productivity per hectare – crops, animals, crop and forestry products, animal products
Economy	Value added	total_expenditures	Total expenditures for the purchase of seeds, fertilizers, pesticides, machinery	Local currency	Total expenditures for the purchase of seeds, fertilizers, pesticides, machinery in local currency
Economy	Value added	value_added	Value added	Local currency	Value added of all agricultural production (crops, animals, crop and forestry products, animal products)
Economy	Value added	value_added_pcapita	Value added per person	Local currency	Value added of all agricultural production (crops, animals, crop and forestry products, animal products) per person
Economy	Value added	value_added_ha	Value added per hectare	Local currency	Value added of all agricultural production (crops, animals, crop and forestry products, animal products) per hectare

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Annex 2. Continued

Group	Subgroup	Column name	Indicator name	Unit of measurement	Description
Economy	Value added	value_added_gvp	Value added on gross value of production (VA/GVP)	Local currency	Value added of all agricultural production / gross value of production
Economy	Income	crop_sales	Revenue derived from crops	Local currency	Total revenue derived from the selling of crops over the past 12 months
Economy	Income	cfp_sales	Revenue derived from crop and forestry products	Local currency	Total revenue derived from the selling of crop and forestry products over the past 12 months
Economy	Income	anim_sales	Revenue derived from animals	Local currency	Total revenue derived from the selling of animals over the past 12 months
Economy	Income	anpr_sales	Revenue derived from animals and livestock products	Local currency	Total revenue derived from the selling of animal and livestock products over the past 12 months
Economy	Income	acrev	Revenue derived from other activities	Local currency	Revenue derived from non-farming-based activities
Economy	Income	finance_exp	Cost of renting land	Local currency	Cost of renting farmland in local currency
Economy	Income	netrev	Net revenue from agropastoral activities	Local currency	Net revenue from all agricultural production (crops, animals, crop and forestry products, animal products)
Economy	Income	netrev_pcapita	Net revenue from agropastoral activities per person	Local currency	Net revenue from all agricultural production (crops, animals, crop and forestry products, animal products) per person in the household
Economy	Income	netrev_ha	Net revenue from agropastoral activities per hectare	Local currency	Net revenue from all agricultural production (crops, animals, crop and forestry products, animal products) per hectare of farmland
Economy	Income	pct_rev_crop_liv	% of revenue derived from crops and livestock	Percentage	Percentage of total revenue that was derived purely from the sale of crops and livestock

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Annex 2. Continued

Group	Subgroup	Column name	Indicator name	Unit of measurement	Description
Economy	Income	intl_poverty	% of people living below poverty level	Percentage	Recorded as a binary (yes/no) answer and presented as percentages in the analysis. This reflects whether the household qualifies as living below the international poverty line of USD 2.15 a day, using 2017 standards.
Economy	Income	depreciation	Depreciation	Local currency	Depreciation is calculated based on initial cost, residual value and number of useful years for the machinery.
Economy	Income	totwage	Expenditures for wages	Local currency	Total expenditures on remuneration of external workers over the past 12 months
Economy	Income	inc3	Qualitative perception of earnings and expenditures	Likert (1-5)	Respondents were asked how they perceive their current agricultural income compared with three years ago, based on the following scale: 5 - Much more income 4 - More income 3 - Same income 2 - Less income 1 - Much less income

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The Agroecology TPP Working Papers contain preliminary or advanced research results on agroecology issues that need to be published in a timely manner to inform and promote discussion. This content has been internally reviewed but has not undergone external peer review.

As agroecology gains recognition for its role in advancing sustainable agricultural and food systems, evidence of its contributions to societal goals is essential for its advancement. This report evaluates the level of agroecological integration in three Kenyan counties involved in the GIZ ProSoil project, which focuses on building capacity to rehabilitate degraded lands through agroecological farm practices. It examines how varying degrees of agroecological integration correlate with multidimensional performance, considering the multifunctionality of agricultural systems. Utilizing the FAO's Tool for Agroecology Performance Evaluation (TAPE) integrated with a robust soil analysis, the study compares 101 farms from the ProSoil group with 100 comparison farms. Key findings indicate that ProSoil participants achieved significantly higher agroecological integration (CAET = 67%) than the comparison group (CAET = 38%). Increased agroecological integration correlates positively with economic benefits, improved agrobiodiversity, biophysical soil health, dietary diversity and food security. However, higher input expenditures were also noted as the level of agroecological integration advanced. While agroecology empowered women in decision making and resource governance, youth engagement in agriculture declined as integration advanced. The report concludes that programmes supporting sustainable farming practices like ProSoil can enhance agroecological integration, contributing to improved economic, environmental and social outcomes. Recommendations emphasize the need for sustainable business models that reduce organic input costs and balance long-term ecological gains with short-term financial needs, particularly through youth-focused initiatives to re-engage them in agroecological transitions.

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About the Agroecology TPP

The Agroecology TPP convenes a broad group of scientists, practitioners and policymakers working together to accelerate agroecological transitions. Since its official launch on 3 June 2021, the TPP has begun addressing knowledge gaps across eight domains that will support various institutions and advocacy groups in key decision-making processes. Its online COMMUNITIES are open to all, providing spaces for members to co-create knowledge, share insights and experiences on various agroecological themes, building collaborative networks with local communities and research bodies to drive agroecological progress for food systems transformation.