Agroecology TPP

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

TAPE application in the context of the Global Programme "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

AE	Agroecology
Agroecology TPP	Transformative Partnership Platform on Agroecology
BMZ	Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung (German Federal Ministry for Economic Cooperation and Development)
BOA	Bureau of Agriculture
CAET	Characterization of Agroecological Transition
CGIAR	Consultative Group on International Agricultural Research
CIFOR	Center for International Forestry Research
CIRAD	Centre de coopération internationale en recherche agronomique pour le développement (French Agricultural Research Centre for International Development)
DeSIRA	EU initiative Development Smart Innovation through Research in Agriculture
DAs	Development agents
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
ICRAF	International Council for Research in Agroforestry (World Agroforestry)
ISFM	Integrated Soil Fertility Management
LDSF	Land Degradation Surveillance Framework
MAP	Measuring Agroecology and its Performance
MoA	Ministry of Agriculture
NP	Non-project affiliated households (comparison group)
NRM	Natural resource management
ProSoil	Global Programme “Soil Protection and Rehabilitation for Food Security”
ProSilience	DeSIRA project "Enhancing soils and agroecology for resilient agri-food systems in Sub-Saharan Africa", implemented by GIZ and embedded in ProSoil
PS	ProSoil project affiliated households
RLUAD	Rural land use and administration
SLMP	Sustainable Land Management Program
SNV	The Netherlands Development Organisation
Stats4SD	Statistics for Sustainable Development
TAPE	Tool for Agroecology Performance Evaluation

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The Measuring Agroecology and its Performance (MAP) project is a collaborative initiative aimed at fostering agroecological transitions by generating evidence of agroecological contribution to societal goals. The MAP project is funded by the German Federal Ministry for Economic Cooperation and Development (BMZ), co-funded by the European Union (EU) and supported by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH through the Global Programme "Soil Protection and Rehabilitation for Food Security" (ProSoil). Embedded in ProSoil is the DeSIRA (EU initiative Development Smart Innovation through Research in Agriculture) project "Enhancing soils and agroecology for resilient agri-food systems in Sub-Saharan Africa" (ProSilience), co-funded by the EU and BMZ. The Tool for Agroecology Performance Evaluation (TAPE) was applied in three districts (Hula, Sodo-Zuria and Walmara) in Ethiopia.

The application of TAPE in Ethiopia was made possible through the support of the Center for International Forestry Research and World Agroforestry (CIFOR-ICRAF), particularly its Kenya country office, which generously provided comprehensive training materials to the CIFOR-ICRAF country office in Ethiopia to train the enumerators. We also appreciate the invaluable contribution of the CIFOR-ICRAF Soil and Land Health team, who travelled all the way to Addis Ababa for the training of the enumerators team in soil sample collection and analysis. We are grateful for the tireless support provided by the staff of Statistics for Sustainable Development (Stats4SD) during the data management process, using online data platforms and data cleaning, analysis, and quality assurance. Our thanks also go to staff from Haramaya University, who shared their previous experiences from the TAPE application and were involved in enumerators training, and we express our gratitude to the CIFOR-ICRAF Ethiopia country office staff for providing all-round support in planning the enumerators field survey, training and validation workshops. Finally, our thanks extend to ProSoil farmers, enumerators, validation workshop participants, and respondents in all three districts for their patience during the extensive data collection process; without their cooperation, this work would not have been realized.

Executive summary

Environmental deterioration, ill health, and premature mortality are interrelated, and all are significantly influenced by global food systems. Currently, there is growing interest in switching to a sustainable system that ensures the production of diversified food products while ensuring the regenerative use of natural resources and addressing societal needs. Agroecology – a transdisciplinary approach simultaneously applying ecological and social concepts and promoting sustainable agriculture and food systems – addresses these needs and has therefore received global attention. In widely promoting agroecology, there is also a need to assess its level of integration and effectiveness. To this end, the Tool for Agroecology Performance Evaluation (TAPE) – a global analytical framework developed with contributions from numerous international organizations and with the Food and Agriculture Organization of the United Nations (FAO) serving as the host – is widely employed to assess the multidimensional performance of agroecology and to generate evidence.

The Measuring Agroecology and its Performance (MAP) project is a collaborative initiative aimed at fostering agroecological transitions by generating evidence of agroecological contribution to societal goals. The MAP project is funded by the German Federal Ministry for Economic Cooperation and Development (BMZ), co-funded by the European Union (EU) and supported by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. In the present study, the MAP project assessed the performance of agroecology in the context of the Global Programme “Soil Protection and Rehabilitation for Food Security” (ProSoil) in three districts in Ethiopia through the application TAPE.

The organizations involved in the MAP project co-developed and implemented two important innovations to TAPE: (i) the combination of the standard TAPE assessment of soil health with the Land Degradation Surveillance Framework-inspired soil sampling and analysis, led by the Center for International Forestry Research and World Agroforestry (CIFOR-ICRAF) Soil and Land Health team; ii) the development and application of a novel data management platform led by Statistics for Sustainable Development (Stats4SD).

Of the 60 districts where ProSoil is being implemented in Ethiopia, TAPE was applied in three of the districts, namely Hula, Sodo-Zuria, and Walmara in the Sidama, South Ethiopia, and Oromia regions, respectively. From each of the three districts, 66 households (respondents) were purposefully selected for the study, where half of the households have active participation in the ProSoil activities (PS households). The other half has no participation in ProSoil activities and constitutes the comparison group (referred to as NP). Overall, the study comprised 198 respondents (99 each for the PS and NP groups).

Before the commencement of the field survey, CIFOR-ICRAF gave the enumerators team two days of training on the TAPE methodology. During the training, the team dealt with the initial questionnaire sections (TAPE Step 0), contextualized the sites, and became familiar with the data entry and submission platform (ODK tool) and a front-end platform (with online help from Stats4SD staff) to be able to navigate the process of soil sampling. Finally, they took a practical field test of the questionnaire and shared their experiences. Data analysis was carried out by Stats4SD, where various plots and charts were used to show the distribution of the overall Characterization of Agroecological Transition (CAET) scores and the 10 agroecological elements for the PS and NP groups of farms.

The Spearman's rank correlation coefficient was employed to visualize the relationships between the different agroecological elements and core criteria of performance. Over 60 stakeholders from various institutions validated the results of the TAPE application during a one-day workshop. Participants had the opportunity to reflect on the implications of these results and conclusions for the institutions and constituents they represented. They were also able to consider how this evidence can support the development and implementation of solutions that will make Ethiopia's agriculture and food systems more resilient, equitable and sustainable.

The findings of this study indicated that the PS group is significantly at a higher level of agroecology transition (CAET = 70%) compared with the NP (the comparison group) (CAET = 55%). Accordingly, most of the PS households (81 out of the 99, i.e., 82%) were "*in transition*" (CAET 60%–70%) and/or at an "*advance*d" (CAET >70%) agroecology level. There were no "*non-agroecological"* farms within the PS group, while 28.3% (28 out of the 99) of NP households were "*not agroecological"* (CAET < 50%), with farms showing a low absolute CAET score (CAET = 25%). PS households scored significantly higher for all 10 agroecology elements (CAET score between 60% and 75%), with the largest difference between the PS and NP (20%) recorded for the Co-creation and sharing of knowledge element. The correlation between the 10 elements of agroecology and the total CAET across the households indicated a strong association and contribution to the overall CAET (>80%) of Synergies (85%***), Efficiency (80%***), Resilience (80%***), Co-creation and sharing of knowledge (85%***), and Circular and solidarity economy (84%***). Likewise, the PS group of farms consistently scored much higher across all three districts, with the highest overall average score (CAET = 73%***) recorded in Sodo-Zuria district.

Results on key dimensions of sustainability indicated that increased integration of agroecology significantly improves multidimensional performances within the PS group. The mean values on several economic indicators (total farm production, value added, and income) were significantly higher with the PS group of farms, which is also consistent with the results across districts. A positive and significant relationship between these variables and the total CAET score (r = +0.27** to +0.32**) was evident, corroborating that integration of agroecology is an effective strategy for improving agricultural productivity, household income, and livelihoods in the study locations.

Improvements in the food security situation were significantly associated with the integration of agroecology (r = 0.2*), particularly with the agroecology elements Diversity (r = 0.40***), Synergies (r = 0.24*) and Efficiency (r = 0.32**). PS farms also showed significantly improved dietary diversity at advanced stages of agroecological transition. Despite greater employment opportunities for women and youth (> 60% scores at both the PS and NP), there was no significant relationship detected between integration of agroecology and women's empowerment, nor youth empowerment. Interestingly, however, significant youth emigration was detected (r = +0.21*) with integration of agroecology, suggesting that young people are not interested in working in agriculture. This could be related to an increase in labour requirements with farm diversification, which leads to more farm activity (e.g., composting, management practices of diverse farm components, etc.) and the resulting drudgery. The percentage of children and family members in households working in agriculture significantly correlated with agroecological integration – with scores on total CAET (r = 0.34**) and elements of diversity (r = +0.38***) – thus indicating agroecology requires more farm labour.

The level of agrobiodiversity – meaning the number and diversity of crop varieties, animal breeds, natural vegetation and pollinators – showed a highly significant and positive relationship (p <0.001) with PS farms, showcasing the contribution of agroecology to healthy and resilient ecosystems. The relationships detected, particularly with the elements of Diversity and Resilience (CAET scores of r = +0.61*** and r = 0.37***, respectively), support this statement. Further, the positive correlation between agrobiodiversity and the Culture and food tradition element (r = +0.38***) implies that the positive impact of agroecological integration goes beyond environmental dimensions, influencing food security (social dimensions) as well. This result signals increased availability and use of local varieties and breeds, along with improved traditional knowledge for food preparation. The highly significant negative correlation detected between the quantity of chemical pesticides used and total CAET, as well as other elements (Synergies, Efficiency and Recycling), could be attributed to the enhanced presence of natural vegetation and pollinators, which favour ecological pest management practices (biocontrol and IPM practices), thus reducing the need for chemical pesticide control and limiting the negative impact on human health.

The mean soil health index, assessed through evaluation of 10 biophysical attributes (TAPE method), was significantly higher ($P<0.01$) with PS farms and has a positive and significant ($p<0.01$) relationship with the total CAET ($r = +0.30^*$) as well as several agroecology elements ($p<0.05$). The positive associations, particularly with the elements Synergies, Efficiency and Recycling ($r = +0.24^*$, $r = +0.28^*$, and $r = +0.31^*$, respectively), confirmed the role of agroecology for soil health maintenance. In contrast to the TAPE-based findings, however, there was no visible improvement detected with the results based on the Land Degradation Surveillance Framework, except a slight change in soil pH (5.9*** at PS vs. 5.6 at NP). This could be attributed to lime application, a standard soil management practice of ProSoil in Ethiopia to ease soil acidity problems in the highlands. Since the primary goal of ProSoil is to improve soil fertility, it is interesting to note that there was no discernible impact on the soil physiochemical properties evaluated. This warrants more research into the reasons behind it.

The insights shared during the validation workshop bear testament to TAPE's practical application. The outcomes discussed at the workshop offer valuable lessons on how technologies advanced by ProSoil have a significant impact on the CAET elements. Additionally, it was indicated that the TAPE results shed light on the requisite policy and financial support from governments and other key players for agroecology's broader implementation.

1 Introduction

Environmental deterioration, ill health, and premature mortality are interrelated, and are all significantly influenced by global food systems. The ways that food is produced, processed, consumed, distributed and disposed of can impact biodiversity, exacerbate climate change, degrade land and soil, and disrupt the cycle of nutrients. There are also inequalities in food systems; about a quarter of children aged under 5 are believed to be malnourished, while one in every five individuals is overweight. Malnutrition, food insecurity and the consequences of climate change are grave concerns, particularly for developing nations.

Agroecology (AE) is a holistic and integrated approach that simultaneously applies ecological and social concepts and principles to the design and management of sustainable agriculture and food systems (FAO 2024). Agroecological approaches are widely advocated and increasingly promoted as promising methods to transform food systems by applying ecological principles to agriculture and ensuring the regenerative use of natural resources and ecosystem services. They also address the need for socially equitable food systems within which people can exercise choice over what they eat, and over how and where their food is produced. For these reasons, agroecology has gained prominence in scientific, agricultural, food-system and political discourse in recent years. It is a transdisciplinary field and comprises the ecological, sociocultural, technological, economic and political dimensions of food systems, from production to consumption (Sinclair et al. 2019).

Agroecology manifests itself at different scales (farm, field and landscape), and there are numerous examples of agroecological practices both globally and nationally. In Ethiopia, the highly sophisticated agricultural system of Konso (South-Western Highlands) where farming is based on an elaborate system of terracing, soil and water conservation practices, irrigation, and multiple cropping systems with the integration of livestock, forestry and crop biodiversity (Förch 2003). For example, the Gedeo home-garden agroforestry system, recently designated as a UNESCO World Heritage landscape (UNESCO 2023), is a complex livelihood system in which all forms of crops – including staple crops (enset*, Ensete ventricosum*), cash crops (coffee) and supplementary crops grow together (Sileshi 2016; CIFOR-ICRAF 2024). There is also parkland agroforestry, though there are only a few examples to mention. However, despite the potential for agroecology to deliver sustainable food system transformation, investment in agroecological approaches remains relatively low compared with other approaches, such as industrial agriculture, which often promotes large-scale single-commodity monocultural practices. To simultaneously address inequity in the food system and enhance the resilience of farming systems to climate change, agroecological approaches should be widely adopted. The necessary support and actions should also be taken to improve enabling policies, the collection of evidence, and knowledge-based decision making.

One of the critical gaps for upscaling agroecology is the lack of adequate evidence that captures its integration and performance across all relevant dimensions of the food system. Building an empirical evidence base is key to realizing agroecology's potential through knowledge-based decision making, while generating polices that promote the integration of agroecology principles and facilitate agroecological transitions. The integration of new agroecological practices – such as planting fruit trees, perennial cereals and vegetated strips – can lead to an advanced level of agroecological transition, but the possible time delay until ecological benefits (from newly introduced practices) are evident may require significant investment (i.e. training, resources) and necessitate a redesign of the farm business.

Agroecology is receiving more attention in national and international policy circles, and this has led to the development of several methods for evaluating its performance, impact and degree of integration (Geck et al. 2023). The level of focus of the different tools developed for measuring agroecological integration and performance has varied, depending on the dimension and the purpose that the tools are intended for. Some are targeted to assessing projects, programmes or policies to find out how much they are aligned with various dimensions of agroecology (GIZ 2022; Olivera and Popusoi 2021); some focus only on farm or household level [Biovision (n.d.a)]; while others are meant for analysis at landscape or community level (Greenberg and Muchero, 2022). Similarly, the size and number of indicators used to measure performance could vary – for example, some tools rely on a single indicator (yield, income etc.), while others may use multidimensional approaches as an analytical framework.

Tools and frameworks for measuring agroecology have evolved over time, as has the concept of agroecology itself. Of the over 60 tools and frameworks that Geck et al. (2023) reviewed, only a few, including the FAO's Tool for Agroecology Performance Evaluation (TAPE), directly combine measuring the degree of agroecological integration with a performance assessment. TAPE (FAO 2019) was developed following a highly participatory process and consists of 10 elements and core criteria that are aligned with relevant Sustainable Development Goals (SDGs) and specific SDG indicators (Mottet et al., 2020). In the present study, which is led by CIFOR-ICRAF under the Measuring Agroecology and Its Performance (MAP) project, the TAPE methodology was used as an analytical framework to investigate the level of agroecological transition and performances due to the implementation of the GIZ ProSoil global project on farms of selected beneficiaries in three districts of Ethiopia.

The GIZ-implemented Global Programme "Soil Protection and Rehabilitation for Food Security" (ProSoil) has been conducted in 60 districts in six regions in the Ethiopian highlands since 2015 (GIZ 2023). The aim of the programme is to support the agroecological transformation of the degradation-prone agricultural system in the highlands of Ethiopia. Overall, the programme contributes towards (i) the scaling and integration of context-based agroecological practices and innovations into the farming systems; (ii) the enhanced agroecological transition of beneficiaries' farms and the community at large; and (iii) practical training for farmers and extension staff on agroecological approaches and practices, facilitating the co-creation and sharing of knowledge. To bring about the expected shift towards agroecology, the project has worked in close partnership with government agencies, the business community, and civil society organizations. Mobilizing the community and setting up Farmer Research Extension Groups (FREGs) and Model Farmers (MFs) within the FREGs were some of the strategies used to demonstrate innovations; scale and disseminate agroecological principles and practices; and to make the change a political, institutional and social priority.

MAP is a collaborative project focusing on evidence generation on the integration and multidimensional performance of agroecology through the gathering and analysis of reliable and consistent data at the farm level through the application of TAPE. CIFOR-ICRAF, through its respective country offices (Benin, Ethiopia and Kenya), was responsible for implementing TAPE, including conducting the survey and validating the results. As part of this process, the agroecological transition level and performance of smallholder farmer beneficiaries of the Global

Programme “Soil Protection and Rehabilitation for Food Security” (ProSoil) were assessed in three districts (Hula, Sodo-Zuria and Walmara) in Ethiopia.

The objectives of the TAPE application on the ProSoil beneficiary farms and the comparison group of households in the selected districts in Ethiopia were:

1. to characterize the agroecological transition (CAET) of both the ProSoil beneficiary group of farms and the non-recipient household groups;
2. to assess the multidimensional performance and agroecological transition levels of the farms in the context of the ProSoil intervention:
3. to analyse the impact of agroecological transition

The findings, while indicating the agroecological transition levels of ProSoil beneficiaries against comparison groups, demonstrated the multidimensional performance of agroecology.

The next section of this report (Section 2) depicts the study site and sampling procedures, describing the three districts and how the households were selected. In Section 3, the main findings on CAET and performances relating to economic, environmental and social indicators are presented, discussed and validated, along with participant responses to participatory questions. Finally, Section 4 includes the conclusions and implications of the study.

2 Methods

2.1 The study districts, sample size and sampling

The Global Programme "Soil Protection and Rehabilitation for Food Security" (ProSoil) has been implemented, in collaboration with the Government of Ethiopia, in 60 districts of Ethiopia situated in the highlands of six regions (Amhara, Oromia, Tigray, Sidama, Central and Southern). Of these, the TAPE study was carried out in three districts (Hula, Sodo-Zuria and Walmara) located in the Sidama, Southern and Oromia regions, respectively. Figure 1 depicts the location of the districts.

The number of kebeles in each of the three districts varied and was 19, 27 and 18 for Hula, Sodo-Zuria and Walmara, respectively (Table 1). From each of the districts, two contrasting kebeles – one comprising ProSoil beneficiary farms (treated) and the other with comparison group of farms (non-treated comparison group) – were purposefully selected in consultation with the ProSoil focal persons; the Bureau of Agriculture (BOA) administration for the respective districts; and the development agents in the kebeles. To ensure comparability between the two experimental groups (the ProSoil beneficiaries and the non-beneficiaries), the kebeles were selected in such a way that the two groups were at least 5 kilometres away from each other. This precautionary measure was taken to limit the farmer-to-farmer exchange of knowledge that often occurs between rural communities when new farming technologies are introduced.

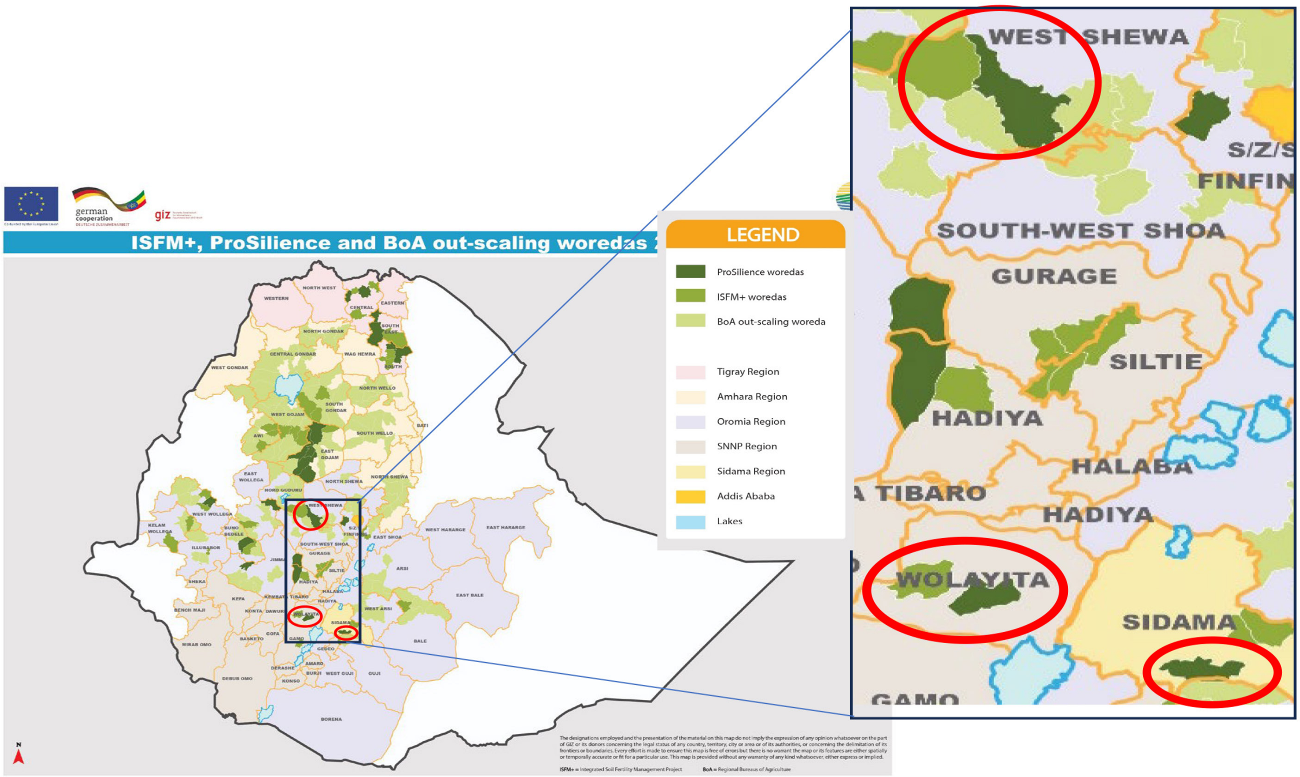


Figure 1. Map showing the three districts [Hula, Sodo-Zuria and Walmara (dark green)] in the Sidama, Southern and Oromia regions, respectively], where the farms for TAPE application were sampled

Table 1. The biophysical, farming system and demographic characteristics of the districts studied

Parameters	Hula	Sodo-Zuria	Walmara
Total area (ha)	15,961	33,749	43800
Mean annual ToC	16.5 (8–19)	19.7 (17.7–21.7)	17 (7 – 27)
Rainfall (mm)	1,200–1,600 (bimodal)	1,200–1,355 (bimodal)	800–1,350 (bimodal)
Altitude (m asl)	1,801–3,000	1,500–2,958	2,060–3,191
Agroclimatic zone*	Dega (72%) and Weynadega (28%)	Dega (10%) and Weynadega (90%)	Dega (61%) and Weynadega (39%)
Total population	176,997 (male 49.9%, female 50.1%)	200,911 (male 49.2%, female 50.8%)	119,458 (male 49.9%, female 50.1%)
Farming practices	Mixed agriculture	Mixed agriculture	Mixed agriculture
Main crops cultivated	Cereals: barley, wheat, maize, teff Pulses: F. bean, field pea, horse bean Root: Irish potato, enset only Fruit: avocado, mango, banana, apple Vegetables: cabbage, carrots, beetroot, lettuce, tomato, onion, garlic, pepper Species: Tena Adam, Besobela, Dinbilal Cash crops: coffee, sugarcane Stimulants: khat (*Catha edulis*), gesho (*Rhamnus prinoides*)	Cereals: same as for Hula + sorghum & rye Pulses: (....all + lentils, chickpea, pigeon pea, cow pea) Root: (....all + taro and cassava, sweet potato) Fruits: (....all + papaya) Cash crop: (.... all + ginger) Industrial crops: cotton, rapeseed, ground nut, gullo/*Jatropha*	Cereals: wheat, barley, teff, maize, sorghum Pulses: same as for Sodo- Zuria Root: Irish potato, Fruits: (insignificant) Cash crops: coffee (insignificant), cereals (especially wheat and teff are important as cash crops) and *Eucalyptus globulus* poles
Trees on farms (& agroforestry)	Wanza (*Cordia africana sp*), Zigba (*Podocarpus gracilior*), Bisana (*Croton macrostachyus*), Birbira (*Millettia ferruginea*), Weira (*Olea Africana*), Tid (*Juniperus procera*), Bamboo, Korch (*Erythrina abyssinica*), *Acacia sp., Eucalyptus sp., Sesbania sesban*	Same as for Hula + sesa (*Albizia gummifera),* especially as shade for coffee	*Olea africana*, Kosso (*Hagenia abyssinica*), Wanza (*Cordia africana*), Tid (*Juniperus procera*), *Acacia sp., Eucalyptus globulus*. (Generally, there is less diversity of tree species).
Livestock	Cattle, small ruminants (goats and sheep), poultry, pack animals (donkey, horse, mule), bees	Same	Same
Number of *kebeles*	19	27	18
Farmland (ha)	10,879 (68% of total land area)	16,440 (49% of total land area)	37,144 (85% of total land area)
Soil type	Loam, silty loam, silt	Loam, silty loam, silt, clay, clay loam, sandy loam	Clay loam and heavy clay (black and red in colour)

* Ethiopia is classified into five traditional climatic zones based on altitude and annual average temperature (MoA 2000; Yohannes 2003): 1. Wurchi (upper highlands) - >3,200 masl & <11.5^{0}C; 2. Dega (highlands) - 2,300–3,200 masl & 11.5–17.5^{0}C; 3. Weynadega (midlands) - 1,500–2,300 masl & 17.5–200C; 4. Kola (lowlands) 500–1,500 masl & 20–270C; 5. Berha (desert) <500 masl & >270C)

Source: BoA offices of the respective districts

Figure 2. General view of the sampling location, *kebeles* (at Sodo-Zuria, and Walmara)

Photo by Fekadu Getachew (lead enumerator)

With the exception of the Global Programme's interventions, which designates the sampling subjects as ProSoil beneficiary vs non-beneficiary, the two representative kebeles selected for the study have similar biophysical (topography), farming system (mixed farming practices) and socioeconomic (typically smallholder) characteristics (Figure 2, Table 1).

On average, a kebele encompasses 650–850 households, depending on the size. In selecting the experimental groups, the kebeles formed the sampling frame. With the help of ProSoil, the GIZ district focal people and the development agent (DA2), 33 farms (households) were selected randomly from each of the two kebeles designated for the treated and non-treated groups, thus bringing the total number of farms (households) selected per district to 66. Overall, this brought the total number of farms involved in the study in the three districts to198.

2.2 Application of TAPE

This study endeavours to evaluate the effects of the ongoing Global Programme "Soil Protection and Soil Rehabilitation" (ProSoil) on agroecological performance and transition among smallholder farms in the districts of Hula, Sodo-Zuria and Walmara in Ethiopia. To assess the impacts of the agroecological transition, comparisons were made between ProSoil beneficiary (PS) and non-beneficiary (comparison) (NP) groups of farms following eight years (2015–2024 of project implementation. The Tool for Agroecology Performance Evaluation (TAPE), developed by FAO (2019), was utilized as an analytical framework and consists of three diagnostic steps (Steps 0, 1 and 2) and a fourth participatory analysis step.

Step 0

Describes the context of the target territory to be assessed, in terms of the farming practices, household type, farm topology, agro-climate etc., thus presenting the enabling environment that exists to support agroecological transitions. This information is obtained through participatory exercises or from a desk review.

Step 1

Characterization of Agroecological Transition (CAET) describes the current status of the territory being assessed based on the scoring of the 10 elements of agroecology: *Diversity, Synergies, Efficiency, Resilience, Recycling, Co-creation and sharing of knowledge, Human and social values, Culture and food traditions, Responsible governance, and Circular and solidarity economy* (Mottet et al. 2020). For the CAET, 36 indices (each belonging to a particular element) were given scores based on five possible predefined options (selected from 0 to 4) for the questions in the TAPE survey. The weaknesses or strengths of the system are determined by adding the scores and standardizing the total on a percentage scale for each element. The CAET score was also used to highlight interaction between the 10 elements and their relative importance for the overall transition process.

Step 2

Lists 10 core criteria of performance indicators (Table 3) to evaluate the multidimensional performance of the systems across various dimensions of sustainability. The core criteria are listed under five key dimensions related to the Sustainable Development Goals (SDGs) – *Environment and climate change; Health and nutrition; Society and culture; Economy; and Governance* – and are considered strategic to framing the results of the assessment and setting a priority for policymakers (Mottet et al. 2020).

Step 3

This step involves a participatory validation of the results obtained from the previous steps, with the inclusion of relevant stakeholders to highlight the strengths and weaknesses of the system assessed and to contextualize the findings. The discussion will help design the enabling environment in the target territory and further support the agroecological transition.

2.2.1 TAPE application: Global context and in Ethiopia

TAPE is believed to enable the production of globally comparable and harmonized evidence. For this reason, it is used across multiple territories and countries to build a global database of evidence on the multidimensional performance of agroecology. The methodology was initially tested in Argentina, Thailand, Angola, the US, New Zealand, Italy and Cuba and is now used throughout a broader set of systems in different regions of the world, including Asia, Africa, the Caribbean, Central Asia and Latin America (Gliessman 2020). In this regard, Cambodia (Bicksler et al. 2023) in the Asian context, as well as Brazil (James et al. 2023), Colombia (Akpatcho et al. 2023) and Argentina (Sokolowski et al. 2023) in Latin America, are a few examples worthy of mention. Some recent applications of TAPE in African countries include Mali (Lucantoni et al. 2023), Senegal (Darmaun et al. 2023), Benin (Akpatcho et al. 2023), Burkina Faso (Tapsoba et al. 2023), Uganda (Bicksler et al. 2023) and Lesotho (Lucantoni et al. 2022) where it has been used to evaluate multidimensional performances of agroecology across diverse agricultural systems in different landscapes. In all cases, the preliminary feedback on the use of the tool has been positive, particularly on its provision of instant feedback to farmers and communities (via the KoBo Toolbox). This has helped facilitate a shift towards participatory appraisal approaches and data-driven problem solving and decision making.

In Ethiopia, TAPE has been employed previously in a couple of cases to study the impact of agroecological practices on transforming the livelihoods and food security situation of vulnerable smallholder farmers in Kembata Tembaro, central Ethiopia (Lucantoni and Jonathan 2023) and to generate empirical evidence on the multidimensional performance of agroecology in mixed and agropastoral farming systems in eastern and southern Ethiopia (Wordofa et al. 2024).

2.3 Data collection and analysis

Before the commencement of the field survey in the selected districts, the enumerators (a team of six) who would conduct the data collection in the field received two days of training on the TAPE methodology. This training was run by CIFOR-ICRAF staff in collaboration with Haramaya University staff, who shared their earlier experiences with the tool. FAO also provided recorded training

Figure 3. Enumerators field training on soil sampling processes by CIFOR-ICRAF soil lab staff

Photo by E. Woldemeskel/CIFOR-ICRAF

materials from an earlier exercise in Nairobi, Kenya. Similarly, the Stats4SD team provided an online demonstration of data collection, recording and submission, using the open data toolkit. CIFOR-ICRAF staff from the ICRAF Soils Theme department provided training on soil sampling procedures in class as well as the practical sampling processes in the field as part of the overall data collection (Figure 3). It is to be noted that the soil characterization in Step 2 – in addition to the physical assessment, following the TAPE Step 2 indicators – was supported by ICRAF's Land Degradation Surveillance Framework (LDSF) procedure, where the collected soil samples were analysed (in ICRAF's soils lab), using a mid-infrared (MIR) spectroscopy technique and wet chemistry methods that followed the LDSF field and lab manual (ICRAF 2023). This was an important modification to the TAPE application in the current assessment conducted through the MAP project. Soil samples were collected (at two soil depths: 20 cm and 50 cm) for each of the 198 households for the soil health assessment in this study.

Following the training session in the classroom, before leaving for the field for data collection, the team pre-filled the initial questionnaire sections and parts of TAPE Step 0 with relevant information on the ground to contextualize the sites. Additional information on Step 0 was obtained through a desk review (sourced from the respective district BoA offices and the GIZ district focal persons), with some indicators – such as farm size and household characteristics – directly obtained during administration of the TAPE questionnaire.

Also, the team familiarized themselves the data entry and submission platform (ODK Toolkit) and the front-end platform (by Stats4SD staff, online) so that they could track the process. Finally, they conducted a practical field pre-test of the questionnaire, each interviewing a farmer (with GIZ district focal persons acting as farmer representatives). Back in the training room, they then verified their data, shared their experiences, raised questions and discussed any problems they encountered in the process.

In the field test (conducted from 15 December 2023 to 15 January 2024), data were collected on the 10 elements of agroecology (guiding the transition to sustainable food and agricultural systems) on 36 indices and the 10 core criteria of performance (comprising 56 indices) from each of the 198 households identified (66 from each of the three districts).

Finally, to contextualize the results of the TAPE application and thus fulfil the goal assigned to Step 3, a one-day workshop was held for relevant stakeholders to engage in a participatory validation of the results (Woldemeskel and Getachew, 2024). The results from TAPE Steps 0, 1 and 2 were presented for validation and debated in this workshop. In total, over 50 participants represented a wide range of stakeholders, including government offices (from 18 different entities), eight CGIAR research centres (including CIFOR-ICRAF), nine non-governmental organizations (NGOs), six donors and four private participants. The varied institutional representation of partners enhanced the interactive conversation that ensued after the PowerPoint presentations on the outcomes of the TAPE application and additional topics during the session.

2.3.1 Data analysis

Data analysis was carried out by Stats4SD, a not-for-profit social enterprise for statistical and data management, which collaborated on the implementation of the MAP project. The distribution of the overall CAET scores, and for the 10 agroecology elements, was plotted for the PS and NP groups of farmers, using violin/box plots (see Figure 6 on Page 24) depicting the agroecological transition levels of the respective farms (PS vs NP). To visualize the relationships between the different agroecological elements and the different core criteria of performance, the Spearman's rank correlation coefficient was employed. Correlation analysis (Spearman's rho) is a bivariate analysis that measures the strength of association between two variables and the direction of the relationship. In terms of the strength of relationship, the value of the correlation coefficient (rs) varies between+1 and -1. As the correlation coefficient value goes towards 0, the relationship between the two variables will be weaker. The direction of the relationship is indicated by the sign of the coefficient; a + sign indicates a direct relationship and a – sign indicates an inverse relationship.

3 Result and discussion

3.1 Step 0 of TAPE: Context of TAPE application

With its landmass stretching from 100 meters below sea level (Danakil Depression in the Afar region) rising to 4,620 meters above sea level (Simien mountains in the north) and corresponding desert-like, tropical and temperate vegetation cover, Ethiopia has a vast diversity of ecosystems, biophysical features and agro-climates. There are different ways of classifying the climatic systems of Ethiopia, and the most commonly used are the traditional and agroecological zones (AEZs) (MoA 2000; Yohannes 2003). According to the traditional classification system, which mainly relies on altitude and temperature, Ethiopia has five climatic zones:

1. Wurchi (upper highlands) - > 3,200 masl and <11.5°C
2. Dega (highlands) - 2,300–3,200 masl and 11.5–17.5°C
3. Weynadega (midlands) - 1,500–2,300 masl and 17.5–20°C
4. Kola (lowlands) 500–1,500 masl and 20–27°C
5. Berha (desert) <500 masl and >27°C

The AEZ classification method, on the other hand, is based on combining growing periods with temperature and moisture regimes. According to this, Ethiopia has 18 major AEZs (Figure 4) where the mean annual rainfall and temperature vary widely. Mean annual rainfall ranges from about 2,000 mm

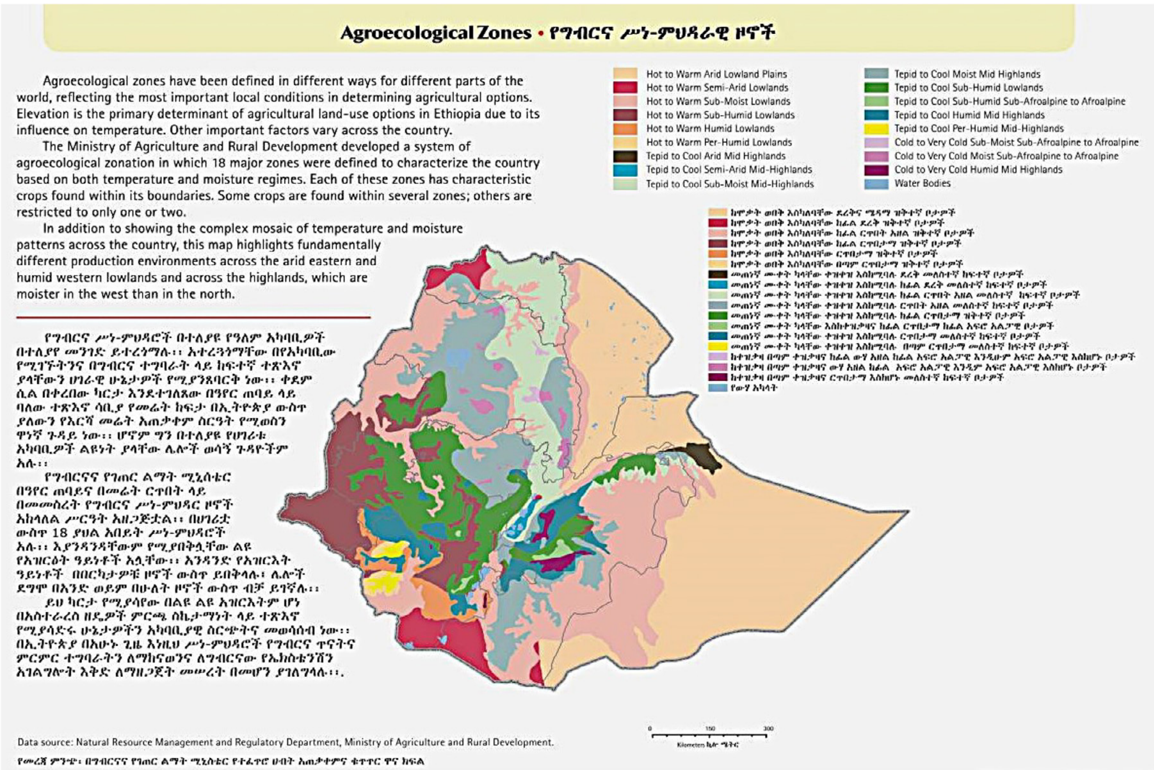


Figure 4. The Agroecological Zones of Ethiopia

Sources: IFPRI, CSA and EDRI 2006

over some pocket areas in the southwest to less than 250 mm over the Afar lowlands in the northeast and Ogaden in the southeast. The mean annual temperature varies from about 10°C on the high tablelands of the northwest, central and southeast, to about 35°C on the northeastern edges.

The three districts (Hula, Sodo-Zuria and Walmara), where the TAPE study took place, are situated in the Dega (highlands) and Weynadega (midlands), according to the traditional classification system (Table 1), whereas all are located in the tepid to cool humid mid-highlands based on the AEZs classification system (Figure 4). This zone is often the most significant agricultural area in the country, with a predominance of different types of cereal crops that offer rather consistent and optimal growing conditions for both annuals and perennials (Table 1). However, it is highly populated (especially Sodo-Zuria and Hula, see under Demography below) and generally threatened by soil depletion and erosion hazards, a reflection of high population, land scarcity and intensive cultivation practices. A detailed description of the districts' general characteristics pertaining to the biophysical, demographic and farming systems – including annual rainfall and temperature – is presented in Table 1.

3.1.1 Rainfall and temperature

The three districts have a bimodal distribution of rainfall, with short rains in March to April and the main rainfall in June to September. Generally, the districts receive between 800 mm and 1,600 mm of rain, with mean temperatures ranging from 16°C to 19°C. The short rain is frequently inconsistent in quantity and timing, occasionally failing completely. Nonetheless, these rains are crucial because they close the food insecurity gap that frequently appears after the protracted dry season (November to February). The short rains also help ease the scarcity of livestock feed by encouraging the growth of fresh sprouts. This is especially crucial for plough oxen, whose labour is essential for soil cultivation at the onset of the main rains.

3.1.2 Farming system

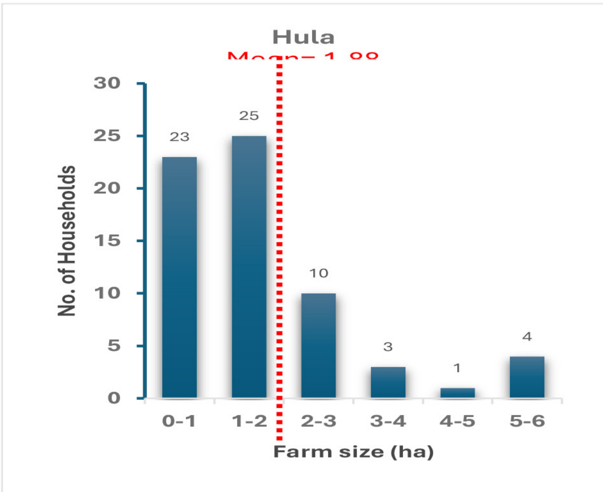
Except for minor differences due to specific local conditions, the diversity of crops cultivated in the three districts is similar. Wheat and barley are the most important cereals in Hula and Walmara, a reflection of their being at a higher elevation (represented by 60%–70% highlands), while maize is the dominant crop in Sodo-Zuria (90% midlands). Enset (*Ensete ventricosum*) is a widely produced staple food in the Hula and Sodo-Zuria districts. Along with the cultivation of crops, animals of all kinds – including livestock (cows, oxen and small ruminants), poultry and pack animals (horses, donkeys, and mules) – are raised together, meaning that farming in the three districts is characteristically mixed. Scattered trees on the farms, and fruits of different kinds, are common sights in the landscape. Of the total land area in the districts, Walmara has the highest proportion (85%) farmed, while Sodo-Zuria has the least (49%).

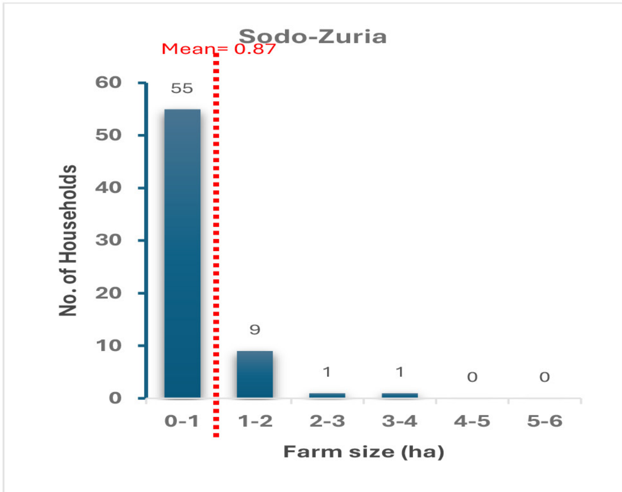
3.1.3 Livelihoods and socioeconomic attributes

Agriculture is a characteristically subsistence- and smallholder-based mixed farming system where crops and animal production are integrated, and only production surplus beyond household consumption is taken into the market. Thus, cash income sources are mainly from the sale of agricultural products (sales of crops, livestock and their products). However, farmers also grow small plots of cash crops for market purposes, such as coffee (Hula and Sodo-Zuria districts) and khat (*Catha edulis*), sugarcane (in Hula), spices (such as ginger), cotton, and rapeseeds (Sodo-Zuria district), while eucalyptus poles are an important source of household income in Walmara district. According to the BoA offices of the respective districts, the household income level is generally low, with the figure for monthly average income being less than ETB 1,500 (Ethiopian birr) (< USD 15).

Demography: Based on the 2019 population projection CSA (2019) (ESS, July 2024), the three districts (Hula, Sodo-Zuria and Walmara) considered in this study have a total population of 176,997 (male 49.9%, female 50.1%); 200,911 (male 49.2%, female 50.8%); and 119,458 (male 49.9%, female 50.1%), respectively. In Ethiopia, the enset growing areas in the central and southern regions are densely populated, with Hula and Sodo-Zuria ranking third and fourth among the 10 most densely populated districts, having a population density of 616 persons and 525 persons per square kilometre, respectively, while this figure is only 182 persons per square km for Walmara. Unlike the observed differences in the population numbers, the proportion of male and female genders in all three districts was similar, with males showing a slightly lower percentage (≈49%) than females (≈51%) in Sodo-Zuria.

Farm holdings: Overall, the farm holdings per household (n = 198) vary within the range of 0.06–8 ha, with an average of 1.65 ha (1.57 ha and 1.74 ha for the PS and comparison groups, respectively). As a reflection of variations in the total population number and density, however, the land-size distribution in the three districts differs, with the lowest average (0.87 ha) recorded in Sodo-Zuria, while this was 1.88 ha and 2.12 ha for Hula and Walmara (Figure 5). Most farmers (approximately 50%) operate on farms less than 1 ha in size. With 55 farmers (83%) of the 66 sampled owning less than 1 ha (0.06 - <1), the shortage of land is a particularly serious problem in Sodo-Zuria district.





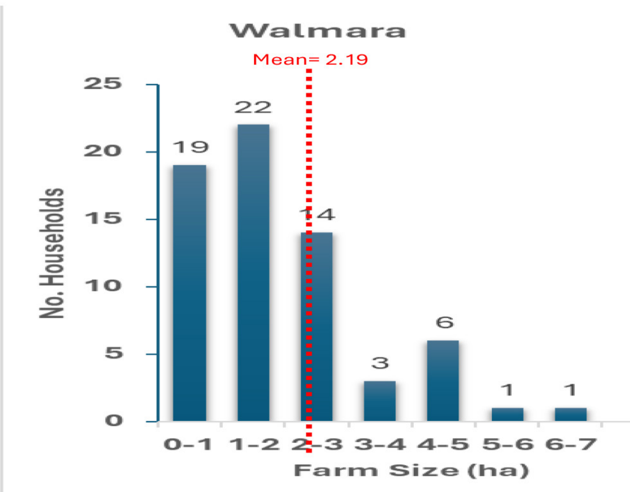


Figure 5. Farm size (ha) distribution in Hula, Sodo-Zuria and Walmara districts. The dotted lines represent the mean farm size.

Source: TAPE survey resultsw

3.1.4 Major problems in farming

Major problems identified in agriculture by the BoA office and representatives of the communities at the ProSoil intervention sites in Hula, Sodo-Zuria and Walmara districts are listed in Table 2.

Population growth: An increase in population numbers is mentioned in all three districts as a key problem. This, in turn, has been associated with a shortage of land, the expansion of settlements, deforestation, and land degradation. According to the Ethiopian constitution, land is communal property and belongs to the people and the state, so farmers have only a right of use. However, adult children in the family have inheritance rights, resulting in land fragmentation and smaller land holding sizes per person. Further, the problem with land shortages aggravates youth emigration to fetch more income as the farm size (usually <0.5 ha) is too small to produce enough to support the family (the average family size is 6–7 persons). The challenge of population pressure, shortage of land, and associated problems is serious for Hula and Sodo-Zuria districts due to their higher population densities (550–650 people per square km). As most Ethiopians live in rural areas, smallholders in the study sites are dependent on natural resources. This will remain so for the foreseeable future, and deforestation and expansion of new settlements will persist unless they are addressed by the right policy and the promotion of appropriate intensification options.

Table 2. Major problems identified by the communities at the ProSoil intervention sites in Hula, Sodo-Zuria and Walmara districts of Ethiopia

Problems	Sodo-Zuria	Walmara	Hula
Population growth	Increase in population number	Population growth	Population increase
	Farmland shortage/settlement expansion/youth emigration	Settlement expansion, land shortage & youth emigration	Land shortage/ settlement expansion/ youth emigration
Soil-related	Soil erosion	Soil erosion	Erosion (especially in highlands)
	Poor soil fertility, severely acidic soil	Soil acidity, depletion, decline in soil fertility	Severe soil acidity, fertility decrease
Deforestation and associated problems	Deforestation	Deforestation (for settlement charcoal, fuelwood, poles…) and loss of biodiversity	Deforestation
	Inadequate clean water; soil erosion	Gradual reduction in stream & river flow	Biodiversity loss
Climate change	Variability in weather conditions (drought, floods)	Fluctuating weather (rainfall & temperature)	Variability in weather (rain, temperature)
Problems related to market and input supply	Poor market linkage (the market was dominated by middlemen)	Poor market linkage and saving	Input price fluctuation (seed, NPS urea pesticides/wheat wagi)
	Increasing price for agricultural inputs	Market fluctuations	
	Limitations in input supply (quantity), including tools/ machinery & quality (poor)		
	Low accesses to loan services		

continue to the next page

Table 2. Continued

Problems	Sodo-Zuria	Walmara	Hula
Crop and animal disease	Crop disease and pestilence		Crop disease / wheat rust and Fusarium
	Not enough services in livestock health system	Animal disease outbreaks	Animal disease (occasional)
Lack of feed resources	Shortage of grazing land	Lack of livestock feed, overgrazing,	
Unemployment	Unemployment (youth emigration)	Lack of job opportunities for youth (emigration)	Youth emigration (labour shortage)
Poor land management	Lack of land-use planning (expanding urbanization disturbs rural land-use system)	Intensive cropping system	
		Poor farming practices (biomass management, irrigation, free livestock grazing, cultivation of steep slopes etc.)	Cultivation of steep slopes (a reflection of population growth, land shortage and expansion of settlement)
Societal & institutional	Lack of good governance; corruption		
	Limitation with agricultural extension services		
	Poor work culture (dependency on aid)		

Soil-related challenges stated include soil acidity, erosion, and a decline in fertility, though the degree of severity varies depending on the district. While the soil erosion problem is predominantly associated with the highlands, soil acidity is severe in Hula and Sodo-Zuria districts. Poor soil fertility is a challenge for all districts and is attributed to de-vegetation, an intensive cropping system, and poor farming practices (biomass management, irrigation, free livestock grazing, cultivation of steep slopes).

Poor input supply and access to market: In the districts considered for this study, agriculture is the source of livelihood. Products that are surplus to household consumption – including crops such as coffee, spices, sugarcane, which generate household income – are sold directly at the local market. However, market participation among smallholder producers is weak owing to difficulties in communication and infrastructure facilities, so it is dominated by middlemen dealers and mini-traders. The small volume of surplus produce from farmers and their inability to aggregate their produce for increased bargaining power force them to depend on brokers or middlemen; the produce is sold at a low price, thus preventing farmers from earning much from their produce. To enable smallholders to participate and benefit from the market, government interventions will need to strengthen institutional services and facilitate communication and information exchange. Similarly, supply chains are inefficient; inputs (chemical fertilizer, pesticides, seeds) are not always available; and products are of low quality and often expensive.

The extension system in Ethiopia is highly structured. The different levels are interconnected from top down (federal-regional-zone-district (*woreda*) and *kebele* (village)) in a highly centralized way. Development agents (DAs), at the bottom of this hierarchy, work at local level and are responsible for guiding and providing all technical support to farmers. However, the extension services can be non-responsive at times, according to respondents from some districts (e.g. Sodo-Zuria). Generally, policies provide a favourable enabling environment for agricultural development, though coordination and follow-up on implementation could be challenging hurdles for the agroecological transition of the food system.

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

This step, the Characterization of Agroecological Transition (CAET), describes the degree of transition to agroecology of the target farms (ProSoil beneficiary versus comparison (non-beneficiary) group of farms). It is based on the 10 elements of agroecology, using scores from descriptive scales established from information collected at the farm/household level.

The results of the CAET score have been used to describe the farms' level of agroecological transition and to pinpoint the agroecological components that need to be prioritized in order to bring the evaluated farms to an advanced level of agroecological transition (Bicksler et al 2020; Lucantoni et al. 2022). While there is no prescriptive threshold defined in the TAPE tool, Lucantoni et al. (2022) suggested and used four categories of CAET scores to describe the agroecological transition levels of farms: *non-agroecological* (CAET < 50), farms at an *incipient level of transition* (CAET 50–60), *in transition to agroecology* (CAET 60–70), and *advanced agroecological farms* (CAET > 70). This scale was followed in describing the farms' level of agroecological transition in this study.

Overall, the results of the CAET scores indicated that the target households in the study area are "*in transition towards agroecology*" and/or at an "*advanced agroecological level.*" This is confirmed by the fact that 58% of the farms have high average CAET scores of > 60, achieving "in transition towards" or "advanced" agroecological levels, while 28.3% of the farms (56 out of the total 198 studied) were already at the "incipient" level of transition (Figure 6; Table 3).

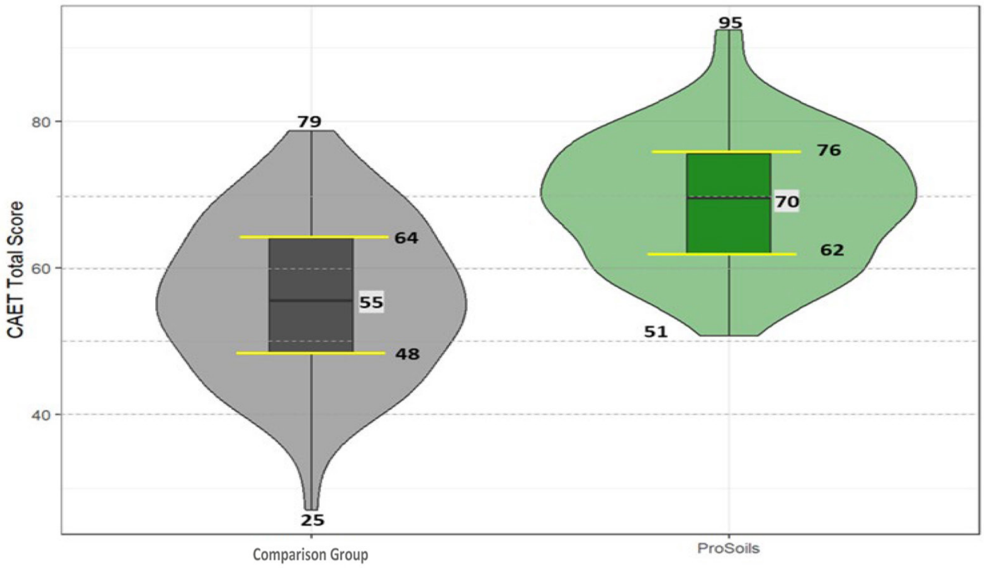


Figure 6. Levels of agroecological transition of ProSoil (PS) and non-ProSoil (NP) or comparison farms as defined by the total CAET score.

Note: The total CAET score on the y-axis indicates the overall level of agroecological integration across farms; the median (highlighted in yellow) and the min. and max. CAET values (yellow lines) along the IQR (interquartile ranges) are for the respective groups.

Table 3. Percent (%) of PS (n=99) and NP (n=99) farms at the different agroecological transition category levels

CAET Score Category	% PS farms	% NP farms
< 50	0	28.3
50 -60	18.2	38.4
60-70	37.4	24.2
>70	44.4	9.1

The distribution of CAET scores of the farms that benefitted from the ProSoil interventions clustered around the median (CAET = 70), with most of these PS farms (81 out of 99) in the "*in transition*" and "*advance*d" agroecological stages. Notably, there is no "*non-agroecological"* farm among the PS group, while the NP (comparison group of farms) had an absolute CAET score at the lower end (CAET = 25), and 28.3% of the farms (28 out of the 99) were "*not agroecological."* However, the CAET values of the NP group were concentrated in the middle (median = 55), which is still significantly lower than that of the PS farms (median =70) (Figure 6; Table 3).

As depicted in Figure 6, the PS group had effectively integrated the ProSoil interventions, which have resulted in advanced levels of agroecological transition, while none of the farms in the beneficiary group was non-agroecological. Though a baseline survey was not conducted, and information was not available when the ProSoil commenced in 2015, the PS farms could be assumed to have had the same status as the comparison group, and the shift in the agroecological transition is attributed to agroecological practices that ProSoil has introduced. On the other hand, a sizable number of the comparison group of farms (33%) achieved "in transition" and "advanced" levels of agroecology, highlighting that even though these farms were not direct beneficiaries of ProSoil, they have been conducting traditional agroecological practices [e.g. use of household waste materials in enset (Ensete ventricusum) and tuber crop plots] or had access to knowledge from ProSoil beneficiaries. Future studies will determine whether a shift in CAET scores will occur in these NP farms, if the observed progress towards a transition to agroecology is maintained, or if the farming system slides back to non-agroecology..

According to results from previous investigations, small farms are more likely than large ones to integrate agroecological practices (Liebert et al. 2024; Ricciardi et al., 2021). This difference is primarily due to limited access to agroecological inputs – such as organic fertilizers and biopesticides – as well as management challenges that arise when implementing agroecology on a larger scale. In our study, the correlation of land holding size to total CAET scores showed a positive relationship, however weak it was (r^2=0.16), implying that the integration of agroecological practices might also be associated with increasing land holding size. Our results corroborate those of Wordofa et al. (2024), who reported that larger land holdings set up agroecological practices successfully. Likewise, farm size correlated well with the element of Diversity (r^2=0.39), demonstrating that increasing land holding size promotes greater agrobiodiversity. The threshold for how large and small farms should be for promoting agroecological practices is a contentious issue and warrants further investigation. In our study, the average land holding size in the study site was 1.65 ha, with 65% of the farms owning 0.5–1.99 ha. Only a handful of farms (10%) had a land holding of 3–8 ha (Figure 5).

3.2.1 The impact of agroecological practices across the 10 elements of agroecology

The strong results obtained in all 10 agroecology elements evaluated show the positive impact of agroecological practices that ProSoil introduced on the beneficiary farms studied (Figure 7; Table 4). While illustrating how far apart the two farm groups are in terms of agroecology integration, the difference in the CAET score index between the PS and NP also reveals the degree of impact made on specific elements and helps identify which element to concentrate on for future improvements. In general, the differences observed between the two groups of farms in any of the considered

Figure 7. A radar plot representing the mean score of the 10 dimensions of the CAET index showing the level of agroecological transition across the PS and NP groups of farms.

Note: The PS has highly significant CAET scores across all 10 elements as compared to the PN group (Table 4).

Table 4. Average scores of the overall CAET and the 10 elements of agroecology for the two farm groups (ProSoil=PS, Comparison group=NP) and their differences (dif.); The stars (*) represent the level of statistical significance at designated p values.

Treatment: PS/NP	Overall CAET	Diversity	Synergies	Efficiency	Recycling	Resilience	Culture & food traditions	Co-creation & sharing of knowledge	Human & social values	Circular & solidarity economy	Responsible governance
PS	69.2***	73.4***	69.6***	60.2***	62.1***	69.5***	74.5***	69.4***	75.6***	69.5***	68.4***
NP	56.0	59.8	56.0	49.0	47.8	56.6	61.5	49.4	67.7	59.0	53.5
Dif.	13.2	13.6	13.6	11.2	14.3	12.9	13.0	20.0	7.9	10.5	14.9

elements range from 7.9% to 20.0% and can be categorized as high (>13%), medium (9%–13%), or low (<9%). Accordingly, six of the 10 elements (Diversity, Synergies, Recycling, Co-creation and sharing of knowledge, Responsible governance, Culture and food tradition) are in the high impact groups; three elements (Efficiency, Resilience, and Circular and solidarity economy) are in the medium category; while Human and social values is the only element showing little difference.

It is noteworthy that the scores for Recycling and Co-creation and sharing of knowledge – the two core elements of agroecology and social elements in the TAPE tool, respectively – were high, demonstrating ProSoil's impacts on beneficiaries both in the adoption of agroecological practices

Table 5. Matrix of correlation between the 10 elements of agroecology and the overall agroecological transition (CAET) across 198 households in three districts of Ethiopia (the Spearman's rank correlation coefficient followed by the stars (*), indicating the level of significance).

AE elements	Diversity	Synergies	Recycling	Efficiency	Resilience	Culture & food tradition	Co-creation & sharing of knowledge	Human& social values	Circular & solidarity economy	Responsible governance	Total CAET
Diversity	1	0.67***	0.47***	0.54***	0.69***	0.57***	0.55***	0.44***	0.48***	0.43***	**0.73*** **
Synergies		1	0.58***	0.67***	0.66***	0.53***	0.69***	0.36***	0.73***	0.63***	**0.85*** **
Recycling			1	0.61***	0.43***	0.45***	0.57***	0.44***	0.44***	0.46***	**0.69*** **
Efficiency				1	0.66***	0.53***	0.64***	0.36***	0.66***	0.56***	**0.80*** **
Resilience					1	0.61***	0.63***	0.35***	0.64***	0.61***	**0.80*** **
Culture & food tradition						1	0.54***	0.43***	0.56***	0.51***	**0.71*** **
Co-c & shar. knowledge							1	0.54***	0.68***	0.64***	**0.85*** **
Human & social values								1	0.46***	0.45***	**0.60*** **
Circ. & solid. economy									1	0.69***	**0.84*** **
Responsible governance										1	**0.79*** **
Total CAET											**1**

*** Very highly significant (<0.001 p value); ** highly significant (<0.01 p value); * significant (<0.05 p value); NS non-significant

(e.g., the recycling of biomass and nutrients; soil management) and the building of farmer knowledge (through training) on agroecological practices and principles, while enhancing networks (providing support) for the horizontal creation and transfer of knowledge and good practices. The existence of local farmers' informal organizations – such as Debo, Edir – and a well-organized public extension system contributed to the success. Additionally, the considerable improvements of the PS group in the element measuring the context-specific knowledge about agroecology (Co-creation and sharing of knowledge, 20%) and the practices on the ground (Recycling, 14.3%) demonstrated the strong interest of farmers to implement sustainable practices and principles.

The difference between the NP and PS households on the Human and social values element was relatively low, but both household groups were already "in transition" or at "advanced" agroecology levels, respectively. This shows acceptable levels of women's empowerment, encompassing involvement in productive decision making; decisions over household income; leadership; and particularly women's access to credit. The latter criterion is part of the ProSoil support package for beneficiary households to improve livelihoods by promoting equity and providing special support to vulnerable women.

Correlation among the different elements of agroecology: The correlation coefficients between the 10 elements of agroecology and overall CAET were analysed to gain insights into the links; the level of strength of association between the variables; and the role of agroecology in achieving synergies as well as different dimensions of agroecological transition and sustainability (Table 5). A "t" test has been applied to all statistical correlations in order to determine their significance. The overall CAET and each of the 10 elements showed a moderate to very strong positive correlation (R > 0.60–0.85), with the "t" test indicating a very highly significant association at p <0.001* (Table 5). The positive correlation depicted the combined contribution of each of the 10 elements to the overall CAET and the synergistic effects between them.

The elements of Co-creation and sharing of knowledge and Synergies (each, R = 0.85***); Circular and solidarity economy (R = 0.84***); Resilience and Efficiency (each, R = 0.80***); and Responsible governance (R = 0.79***) showed the strongest relationships, which suggested greater contributions to the overall CAET and to the agroecological transition and transformation of farming systems in the targeted districts. The strong link of the elements of Circular and solidarity economy with the overall CAET score (R = 0.84***), in general, and the highly significant associations detected, particularly with the elements of Synergies (R = 73) and Resilience (R = 0.64***), suggested the existence of local markets contributed to the overall agroecological transition in the area. More advanced agroecological farms tend to adapt practices (as demonstrated by the high and significant correlation with Co-creation and sharing of knowledge) that enhance ecological services, which contribute to the increased production and commercialization of agricultural outputs through local circuits and territorial markets. The markets, along with the adoption of good agroecological practices assisted by networks for the learning and sharing of knowledge among farmers and communities, are important vehicles for advancing agroecological transitions and the gradual transformation of food systems (Niggli et al. 2023).

3.2.2 Characterization of the Agroecological Transition (CAET) across districts:

Violin and box plots with average CAET results for the PS and NP farms in the three districts (Hula, Sodo-Zuria and Walmara) are presented in Figure 8. Average CAET results for all 10 elements of agroecology for the two farm groups in each district are presented in Table 6. Generally, the mean CAET scores across all three districts displayed a clear pattern revealing that the PS group was at higher agroecological transition levels than the comparison group (NP). This is also true for each of

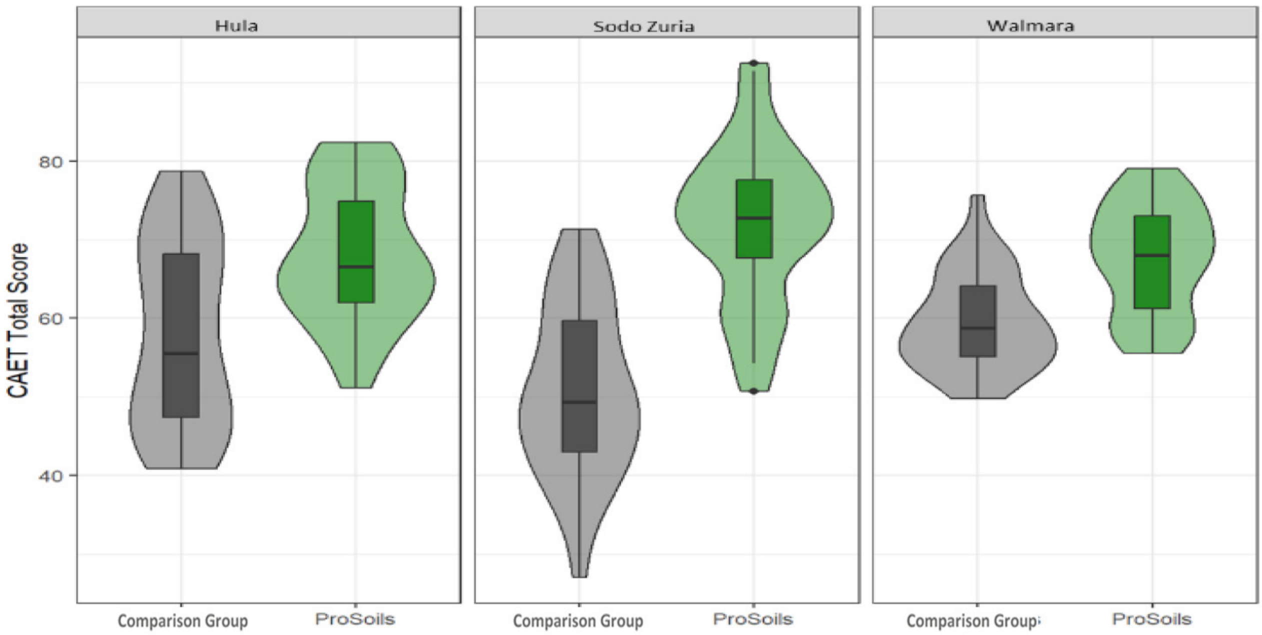


Figure 8. Levels of agroecological transition of ProSoil (PS) and comparison group (NP) farms in the project's target districts (Hula, Sodo-Zuria and Walmara), as defined by the total CAET score

Note: The total CAET score on the y-axis indicates the overall level of agroecological integration across farms; the box inside the radar plot represents the IQR (interquartile ranges) for the respective groups.

Table 6. Average scores of the overall CAET and the 10 elements of agroecology for the two farm groups (ProSoil=PS, Comparison group=NP) and their differences (dif.); the stars (*) represent the level of statistical significance at designated p values.

Survey districts	Treat. PS/NP	Total CAET	Diversity	Synergies	Efficiency	Recycling	Resilience	Culture & food traditions	Co-creation & sharing of knowledge	Human & social values	Circular & solidarity economy	Responsible governance
Walmara	PS	67.5***	69.1NS	62.7 NS	58.4***	58.7***	67.1**	78.3**	67.0***	78.5*	68.3 NS	67.3**
	NP	59.5	66.9	58.1	48.6	47.6	61.1	71.8	47.1	73.1	63.5	57.4
	Dif.	8	2.2	4.6	9.8	11.1	6	6.5	19.9	5.4	4.8	9.9
Hula	PS	68.1***	74.7**	71.5*	59**	59.9**	68***	70.3***	66.8*	72.5 NS	68.2 NS	69.9***
	NP	57.9	63.1	61.4	48	49.8	55.6	61	57.3	67.2	61.7	53.8
	Dif.	10.2	11.6	10.1	11	10.1	12.4	9.3	9.5	5.3	6.5	16.1
Sodo-Zuria	PS	72.1***	76.6***	74.9***	63.1***	67.8***	73.2***	74.9***	74.5***	75.8***	72.0***	68.1***
	NP	50.7	49.5	48.5	50.3	45.9	53.2	52	43.6	62.8	51.8	49.5
	Dif.	21.4	27.1	26.4	12.8	21.9	20	22.9	30.9	13	20.2	18.6

Notes:
*** = Significant at p <0.001
** = Significant at p <0.01
* = Significant at p <0.05
NS = non-significant

the 10 agroecology elements: the PS group in all three districts consistently scored higher CAET scores for any of the elements considered (Table 6).

Interestingly, despite the uniformity of the GIZ ProSoil interventions introduced, the comparative impact and extent of agroecological integration varied in different districts. The PS farms in the Sodo-Zuria district demonstrated an advanced level of agroecological transition (CAET > 70), while those in Hula and Walmara districts were "in transition" to the agroecology stage (with mean district CAET scores of 60–70) (Table 6). Farms in Sodo-Zuria district had the highest average scores for nine of the 10 elements of agroecology (CAET > 70) (Table 6).

PS farms in Sodo-Zuria were advanced in the elements of Diversity (76.6), Synergies (74.9), Recycling (67.8), and Co-creation and sharing of knowledge (74.5), indicating differences of > 20 points compared with NP farms, which measured an average CAET score < 50 (non-agroecological). The high levels of integration between the different components of the agroecosystem (Diversity, Synergies, Recycling) are impressive and support various management techniques (e.g. for biomass, composting, animals, crop and tree components) that boost soil health, promote ecological services, reduce inputs and foster self-sufficiency for agricultural production. The high score for the element Co-creation and sharing of knowledge (a difference of 31 points) indicate the efficiency of local networks in learning and sharing information on improved practices, while the score for the element Circular & solidarity economy (difference of 20.2 points) shows the efficiency of local and territorial markets for their agricultural production, and connections between producers and consumers. The PS farms in Hula district also have the largest point differences (10.1–12.4), compared with the comparison group, for the elements Diversity, Synergies, Recycling, Efficiency and Resilience, indicating a high level of agroecological integration for different components and a link to management practices that support soil fertility.

The statistically highly significant score of the PS group for the element of Responsible Governance (point difference of 9.9–18.6) suggested that these farms are generally more organized, empowered and resilient. In Ethiopia, farms in districts are often organized into a producers collective with marketing associations at *kebele* level, led by a group of elected committees.

3.3 Step 2: Multidimensional performance of agroecology

In this section, average results of the core performance criteria (economy, environment and social dimensions, including health and nutrition) that are considered essential to assessing the multidimensional performance of production systems in agriculture, are presented for the respective (PS and NP) farms across the study location. In addition, the links between the variables of Step 1 and Step 2 were analysed to assess the multidimensional performances and the role that the ProSoil interventions played in the different dimensions and in the core criteria evaluated.

3.3.1 Economic dimensions

Table 7 presents the average results of some of the indicators of performance under the economic dimensions: total output, total expenditure, value added, and perception of earnings and expenditure, along with their correlations with the total CAET and the other elements of agroecology.

The mean total output and value added (wealth created by the farms' agricultural activity) showed a significant increase ($P<0.05$) for the ProSoil group (PS) farms versus the comparison group. Also, the correlation analysis indicated a positive and statistically significant relationship between these variables (total output and value added) and the total CAET score (r = +0.32** and r=0.27**, respectively). A strong positive correlation was particularly evident between these economic variables (total output and value added) and a number of agroecological elements, including Diversity (r=+0.50*** and r = +0.31**, respectively), Resilience (r = +0.35*** and r=+ 0.32***), and Co-creation and sharing of knowledge (r = +0.23* and r=+ 0.25*), showing a strong and positive impact that agroecological transition had on the economic performance of the beneficiaries. Farms in transition to, or at an advanced level of, agroecology are more diversified and include the production of different kinds of crops, livestock and vegetables, thus showing significantly higher scores in total output (more productive), added value (more wealth creation) and resilience. The positive correlation detected between Co-creation and sharing of knowledge and the economic variables (r = +0.25*) could be related to the enhanced integration of agroecological practices that favoured farm diversification and productivity, eventually contributing to increased economic returns.

The mean total expenditures (for the purchase of seeds, fertilizers and pesticides) were statistically similar for both groups of farms. However, the negative correlations of total expenditures with CAET scores of agroecology elements – though not significant – depict an encouraging sign that practicing agroecology could result in reduced production input costs. This trend has been clearly shown with the PS farms, where expenditure for inputs declined with the increased integration of agroecology (Figure 9A). With advances in agroecological transition, dependence on external inputs is expected to diminish as internally produced or recycled inputs are substituted with ecosystem services provided by the agroecosystem.

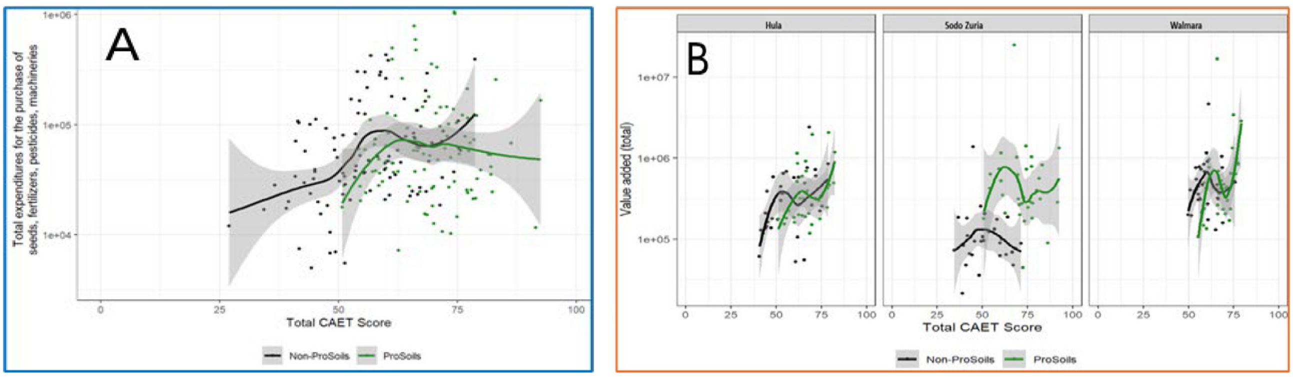


Figure 9. A. Correlation between CAET score and the total expenditure on farm inputs among PS and the comparison group (NP). Note that input expenditure within the PS is consistently lower, and agroecological integration probably reduces farm input costs; B. Correlation between CAET score and total value added within PS and NP (comparison) farms.

Table 7. Mean values and correlations between CAET scores (total CAET and other elements) and some indicators of economic performance (total output, expenditure, value added and farmers' perception of farm earnings (PS=ProSoil farms; NP= Comparison group farms) (Mean values are in '000 Ethiopian birr (ETB)) (n=198)

Type of farm	Total output	Total expenditure	Value added	Qualitative perception of earnings and expenditures[a]
PS (ProSoil)	1,089*	114[NS]	950*	4 ***
NP (Comparison group)	401	87	394	2
Correlation with CAET	+0.32**	NS	+0.27**	+0.31**
Correlation with other elements	+0.50*** (Diversity) +0.32*** (Resilience) +0.23* (Co-creation & sharing of knowledge)	-0.044 (Recycling) -0.020 (Efficiency) -0.050 (Circular & solidarity economy)	+0.31**(Diversity) +0.35*** (Resilience) +0.33** (Culture & food tradition; +0.25* (Co-cr. & shar. knowledge.)	+0.25* (Diversity); +0.23* (Synergies) +0.22* (Resilience); +0.21* (Human & social values); +0.25* (Circular & solid. economy); +0.22* (Responsible governance)

*** Very highly significant (<0.001 p value); ** highly significant (<0.01 p value); * significant (<0.05 wp value); NS non-significant.

Note: a An increase in the level of agroecological integration is perceived to yield more income from farm produce among farmers implementing ProSoil interventions, while the reverse perception is true in the comparison group (NP). (Respondents were asked how they perceived their current agricultural income to that of three years ago on the following scale: 5 - Much more income; 4 - More income; 3 - Same income; 2 - Less income; 1 - Much less income)

Likewise, the total value added in all three districts studied (Hula, Sodo-Zuria, Walmara) showed a significant increase with the ProSoil farms and was positively and significantly correlated with the total CAET score (Figure 9B). On the other hand, an increase in total value added with the NP farms could be attributed to an increase in external production inputs (Figure 9A), which is assumed to be unsustainable over time. This is evidenced by the decreasing trend of total value added with the NP group as total CAET scores increased, particularly in Sodo-Zuria and Walmara *woredas* (Figure 9B).

When respondents were asked to compare their present agricultural revenue to that of three years ago, their qualitative judgment of earnings and expenses revealed that they have been making more money since they began using agroecological practices promoted by ProSoil (Table 7).

3.3.2 Environmental dimension

The level of agrobiodiversity (the Gini-Simpson index for crop varieties, animal breeds, natural vegetation, and pollinators); soil health; the integrated pest management (IPM) index; and the quantity of chemical pesticides used were the main indicators assessed in measuring environmental performance.

Accordingly, the agrobiodiversity elements – i.e. the number of species, crop varieties and animal breeds, as well as the prevalence of natural vegetation and pollinators – were significantly higher (p <0.01) for ProSoil households (Table 8). Further, the correlation analysis between these variables and total CAET, and the CAET for individual agroecological elements as well, showed a highly significant and positive relationship, confirming that agroecological practices favour the functioning of natural ecosystems where biodiversity, complex structure, interactions and synergies among components are enhanced (Wezel et al. 2020). Relevant to this, it is noteworthy that there are highly significant positive relationships between CAET scores for agroecology elements (Diversity, Synergies,

Table 8. Mean values and correlations between CAET scores (total CAET and other elements) and indicators of environmental dimension (number of sp. and var. of crops; number of sp. and breeds of animals; presence of natural vegetation and pollinators; quantity of chemical pesticides used and soil health index) (PS=ProSoil farms; NP= Comparison group farms) (Mean values are in '000 Ethiopian birr (ETB)) (n=198)

Types of farms	Number of species & var. of crops	Number of sp. & breeds of animals	Presence of natural vegetation & pollinators	Quantity of chemical pesticides used	IPM score ++	Soil Health Index
PS	5.6***	3.2***	48.7**	16 NS	16.5**	3.2**
NP	4.2	2.6	42.2	13	10.5	3.0
r with total CAET	+0.12 NS	+0.37	+0.47***	-0.25*	NS	+0.30**
r with other elements	+0.2* (Resilience)	+0.61***(Diversity) +0.37*** (Resilience) +0.22* (Synergies) +0.42*** (Cult. & food tra.) +0.27* (Human & social va.) +0.20* (Circular & sol. eco) +0.20* (Responsible gover.)	+0.52***(Diversity) +0.52*** (Resilience) +0.53*** (Synergies) +0.31** (Efficiency) +0.38***(Co-cre. & shar. kn.) +0.34***(Circul. & solid. econ. +0.42***(Responsible govern.)	-0.25*** (Synergies) -0.39*** (Efficiency) -0.21* (Recycling)	NS	+0.20* (Diversity) +0.25* (Resilience) +0.24* (Synergies) +0.28* (Efficiency) +0.31* (Recycling) +0.29* (Co-cre.& shar. kn. +0.26* Circ & solid. econ.

*** Very highly significant (<0.001 p value); ** highly significant (<0.01 p value); * significant (<0.05 p value); NS non-significant

Efficiency, Resilience and Recycling) and one or the other agrobiodiversity attributes measured (Table 8). Likewise, the positive correlation between the CAET score for the element of Culture and food tradition and the agrobiodiversity indices implies that the positive impact of agroecological integration goes beyond environmental dimensions, enhancing food security (social dimensions) as well and resulting in increased availability and use of local varieties and breeds, along with improved traditional knowledge for food preparation.

Interestingly, the quantity of chemical pesticides used has a significantly high negative correlation with the total CAET (r = -0.25*) and individual agroecology elements (Synergies, Efficiency and Recycling, r = -0.25***, r = -0.39***, and r = -0.21*, respectively). This could be attributable to the enhanced presence of natural vegetation and pollinators, which in turn favour ecological pest management practices (biocontrol and IPM), thus reducing the need for chemical pesticides with the intensification of agroecological practices in farming systems.

The mean soil health index, which is measured through a qualitative assessment of 10 soil health indicators, was significantly higher (P<0.01) for PS households than the comparison group and has a positive and significant (p<0.01) relationship with the total CAET (r = 0.3) as well as several of the agroecology elements (p<0.05) (Table 8). The positive correlation, particularly with that of Synergies, Efficiency, and Recycling (r = 0.24*, r=0.28*, and r=0.31*, respectively), demonstrated that improved soil management practices are perceived by farmers as useful aspects of agroecological integration

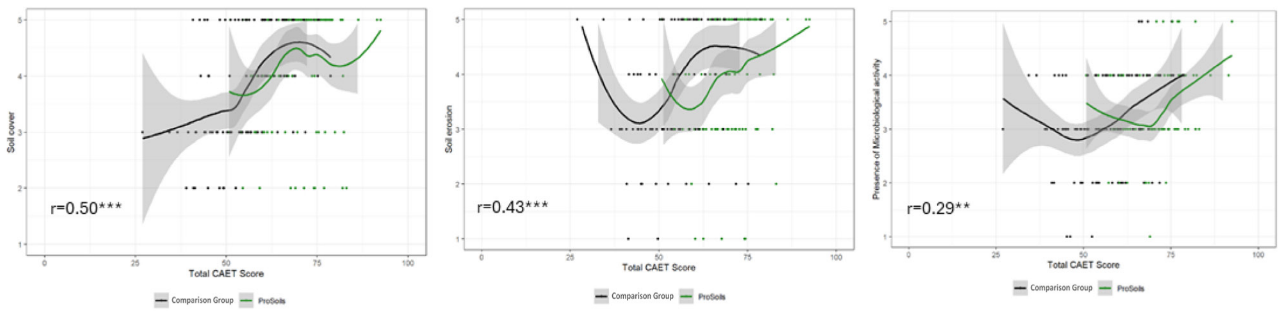


Figure 10. Correlation between CAET score and soil cover (left), soil erosion (center) and presence of microbial activities (right). A score of 5 on the soil cover graph signifies that over 50% of the soil is either covered by live vegetation or residues. Likewise, a score of 5 on the soil erosion graph indicates the absence of erosion.

for soil health maintenance. Similarly, the observed positive correlation between the Soil Health Index and social elements, like Co-creation and sharing of knowledge (r = 0.29*), highlighted the importance of learning, dissemination and knowledge transfer on soil management practices through local networks.

Generally, compared with the comparison group, farms that implemented ProSoil interventions showed significantly ($p<0.01^{**}$) higher scores across many biophysical soil health indicators. Soil cover, soil erosion, and the presence of microbial activities were among the indicators that displayed the strongest correlations with the CAET scores (Figure 10). With increased diversification (trees, crops, and soil organisms) at advanced levels of agroecology, more residue and soil cover, less soil erosion, increased soil moisture, and soil ecological activities (macro, meso, and micro) are to be expected, thus improving the overall soil health status in farming systems.

The LDSF used the results from the analysis of the physicochemical properties of soil samples to infer soil health, in contrast to the TAPE, which assessed the soil health status using a set of biophysical attributes. Accordingly, soils from all three study districts were characteristically high in clay content (>60%), thus typically represent clay soils. The soil fertility and its ability to adequately supply plant nutrients are a sum of several physicochemical attributes. The SOC, total N, phosphorus and potassium content; as well as the pH, and CEC are often considered the most determinant ones. The interpretation of results on these variables revealed that the soils on both the PS and comparison farms are alike and moderately acidic, with an optimum level of SOC (%), TN (%) and K (mg/kg) content, as well as CEC (cmol/kg), and a very high Ca (mg/kg) content and PSI level (Table 9). In addition, among all the different parameters assessed, significantly higher mean values were recorded for only a few of them (pH, Ca content and CEC) at the PS farms. Despite this, however, the soil conditions in both household groups fall under the same soil fertility categories (Table 9), implying that the ProSoil soil management intervention has little or no effect on soil health conditions at PS farms.

Likewise, the correlation of agroecological integration level (CAET scores) with physicochemical indicators of soil health – such as SOC, TN, pH – showed no significant relationship, except for a few outliers within both the PS and comparison households at advanced agroecology level, which displayed improvements (Figure 11A, B, C). Despite a better agrobiodiversity status (crops, trees, natural vegetation) and an associated increase in soil debris and microbial activities observed (Table 8, Figure 10) with the integration of agroecology, the lack of significant improvements in the soil physicochemical indicators assessed might be linked to the soil dynamics related to slow

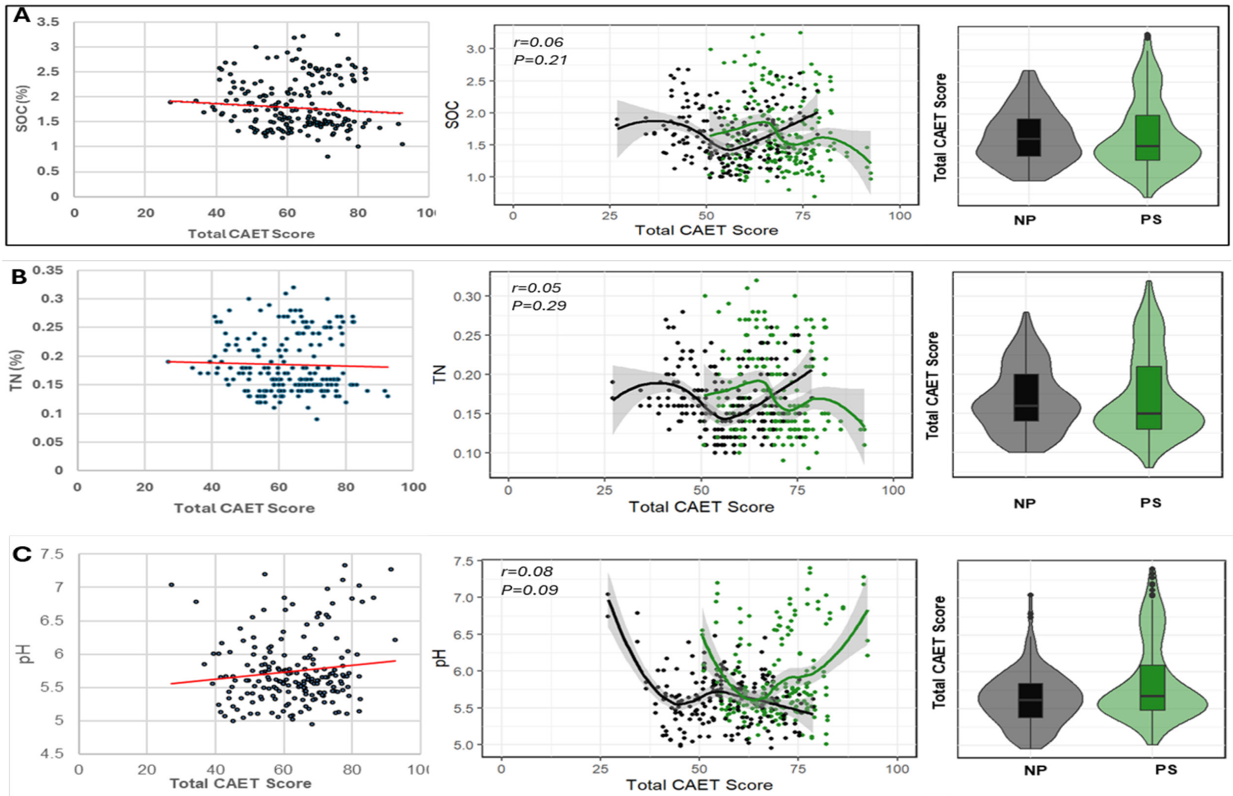


Figure 11. Correlation of agroecological integration level (CAET scores) with soil organic carbon content (A), total nitrogen content (B); and pH for the total dataset (left) and disaggregated by ProSoil and comparison groups represented on scatter (centre) and violin box (left) plots

Table 9. Sample results of the physicochemical analysis for some of the soil measures based on the LDSF

Measure	Group	Mean	Median	SD	IQR	Interpretation ®
SOC (%)	PS	1.7	1.5	0.5	1.3 - 2.0	Optimum
	NP	1.7	1.6	0.4	1.3 - 1.9	
pH	PS	5.9***	5.7	0.5	5.5 - 6.1	Moderately Acidic
	NP	5.6	5.6	0.4	5.4 - 5.8	
Total nitrogen (TN)	PS	0.2	0.1	0.1	0.1 - 0.2	Optimum
	NP	0.2	0.2	0.0	0.1 - 0.2	
Phosphorus Sorption Index (PSI)	PS	122	117	35	100 - 131	Very High
	NP	125	124	22	112 - 136	
Ca (mg/kg)	PS	1,776***	1,396	1,126	923 - 2566	Very High
	NP	1,426	1,366	713	922 - 1799	
K (mg/kg)	PS	366	335	158	263 - 453	Optimum
	NP	388	386	151	264 - 503	
CEC (cmol/kg)	PS	22***	22	3.6	20 - 25	Optimum
	NP	20	20	3.1	18 - 22	

* means significant at p <0.001; the categorization of low, optimum, moderate, high is based on median value and the critical levels indicated in the LDSF; n=396

litter decomposition, microbial activities and the nutrient release process, and immediate changes are unlikely (time lag). Soil nutrients – such as N, P, K – might be temporarily limiting (tied up in the decomposition process) in the soil system (notably at the PS farms, see Figure 11B) and in the contrasting increase in soil pH, Figure 11C (which might be linked to a higher soil Ca content, possibly from decomposition at PS farms; see Table 9).

The main focus of the GIZ ProSoil global project is to promote food security and climate protection through the implementation of agroecological approaches that conserve soil and rehabilitate infertile soil in climate-smart, environmentally friendly ways (GIZ July 2023) Through the training of smallholder farmers and long-term support for climate-smart agricultural and agroecological practices, the project is generally successful in enhancing agrobiodiversity and productivity, household income and resilience. However, the soil management practices have not brought the anticipated impact. Specifically, the results from the LDSF (in contrast to the TAPE method) did not demonstrate any visible improvement on soil health. The observed differences in soil biophysical (TAPE) and physicochemical (LDSF) results might be attributable to differences in indicators used as well as analysis, or they might be masked. This calls for further in-depth investigation.

3.3.3 Social, health and nutrition dimensions

The indicators of performance assessed in the social, health and nutrition dimensions were: (i) *Women's empowerment* (based on five dimensions: involvement in production; involvement in income decisions; asset ownership; time use allocation; and leadership); (ii) *Youth empow*erment (youth employment opportunities and emigration indices); (iii) *Dietary diversity and food security*; and (iv) *Exposure to pesticides*.

Women's empowerment: Analysis of the women's empowerment score (A-WEAI) and Gender Parity Index (GPI) did not reveal any statistically significant differences between the PS and NP groups of farms. Nor did it demonstrate any correlation with the total CAET or other agroecological elements, except for Culture and food traditions (r=0.31**) (Table 10). This shows that the integration of agroecology in farming, on its own, may not necessarily bring about improvements in women's empowerment. Perhaps, the issue relates to the sociocultural mindset on gender equality, which could be overcome through education and awareness creation to bring about societal changes in attitudes. On the other hand, women may benefit from the integration of agroecology through an enhanced capacity to produce diversified, healthy, nutritious and culturally appropriate food for household consumption, thereby ensuring family food security, as evidenced by the significant positive relationship between the women's empowerment score and the element Culture and food tradition.

Youth empowerment: The analysis of data on youth employment indicated no significant difference between PS and NS farms, nor did it correlate with the total CAET and other elements, thus indicating that integration of agroecology (the ProSoil intervention) has no influence on youth employment (Table 10). However, there is a positive and significant link (r = 0.21) between the youth emigration index and the overall CAET score, suggesting that the youth in our study are not interested in working in agriculture and that they would prefer to emigrate in order to find a job elsewhere. This goes against the results of earlier research that showed young people in more advanced agroecological production systems are less inclined to walk away from the farm and would prefer to continue working in agriculture (Lucantoni et al. 2023; 2022). It is noteworthy that the youth emigration index also significantly correlates with some of the agroecology elements evaluated, including Circular and solidarity economy, Resilience, and Culture and food tradition (r = +0.20, r = +0.22, and r = +0.25, respectively). This supports our finding that young people dislike engaging in agriculture and have a growing interest in emigration, despite improvements in household nutrition and income, as well as the resilience observed with the integration of agroecology. This topic warrants more investigation.

Table 10. Correlations between CAET scores (total CAET and other elements) and social dimensions (women and youth empowerment, as well as various family members in the household working in agriculture) and mean values at ProSoil (PS) and comparison (NP) group of farms for the variables (n=198)

Group of farms/ dimensions	Women's empowerment score A-WEAI (0-100%)	Gender Parity Index (0-100%)	Youth employment score (0-100%)	Youth emigration score (0–100%)	Percentage of female adults, youth, children, and family in the household working in agriculture (0–100%)			
					Female adults (15+ years old)	Youth (15–34 years old)	% children	% family
PS	67.4 NS	113 NS	62.8 NS	28.8 NS	50.0 NS	57**	20.5**	69*
NP	66.5	118	62.2	30.8	46.4	44	8.2	63
Correlation (r) with total CAET	NS	NS	NS	+0.21*	NS	NS	+0.24*	+0.23*
Correlation (r) with other elements	+0.31** (CFT) +0.27* (Effi)	+0.30** (CFT)	-	+0.22* (Res) +0.20* (CiSE) +0.25* (CFT)	-	+0.27** (Res)	+0.24* (Div) +0.34** (Effi) +0.25* (Res)	+0.37*** (Div) +0.33** (Res) +0.25* (CFT) +0.20* (CiSE) +0.21* (Rgov)

Note: (*) indicates level of statistical significance: *** = at p <0.001 (very highly significant) ; ** = at p <0.01(highly significant); * = at p<0.05 (significant) ; NS =non-significant; Div=Diversity, Syn=Synergies, Effi=Efficiency, Rcy=Recycling, Res=Resilience, CFT=Culture & food tradition, CoSK= Co-creation & sharing of knowledge, HSV=Human & social values, CiSE=Circular & solidarity economy, Rgov=Responsible governance.

Household members working in agriculture: In general, PS had a significantly higher percentage of family members (including youth and children) working in agriculture in the household than did the comparison group (Table 10). This is particularly the case for the percentage of children and youth (15–34 years old), which has a significant association with the overall CAET score as well as other elements, suggesting more agroecological integration leads to an increased need for farm labour. Further, agroecological integration was associated with more family labour demand, as shown by the significant and positive relationships with the elements of Diversity (r = +0.24* and r = +0.37***), Resilience (r = +0.25* and +0.33**), and Efficiency (r = +034**), suggesting that farm diversification (where agricultural production is primarily managed by family members) probably increases obligations for children and youth, with no visible benefits to them. In rural communities, youth and children are culturally obliged to help with family farming activities, which can be cumbersome at times and might contribute to the apathy towards engaging in agriculture. As a result, it is understandable that young people increasingly seek to emigrate elsewhere to look for a better future.

Dietary diversity and food security: Compared with the NP group of farms, the ProSoil farms had a significantly higher (at p<0.001) dietary diversity index score, which indicates increased availability of diversified edible products within these farms (Figure 12). Further, improvements in the food security situation were significantly associated with the integration of agroecology (r = 0.2*), particularly with the elements of Diversity (r = 0.40***), Synergies (r = 0.24*), and Efficiency (r = 0.32**). This shows that households that are more advanced in their agroecological transition ensure on-farm availability of diverse food, boosting food security and resilience to shocks.

The significant positive relationship between food security and elements of a Circular and solidarity economy (r = +0.39***) indicates the availability of markets to sell household produce locally but also to spend what they earn to buy food products that they do not have. This may partially explain why there were no statistically significant differences in expenditures for food between the two groups of farms (Figure 12). In some communities where the saving culture is not well established – i.e. where saving for future investments is not a priority – earnings are spent on food items that they do not produce on the farm.

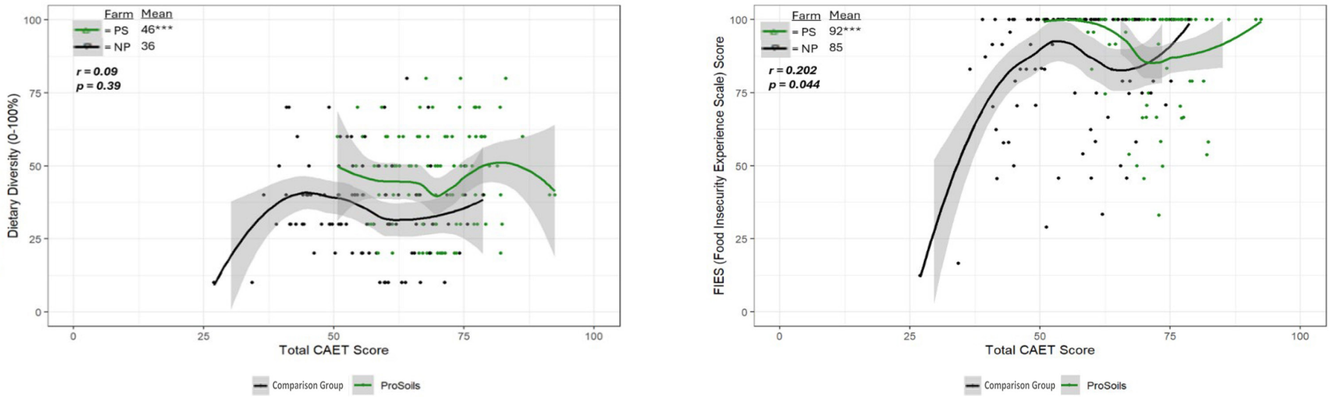


Figure12. Correlation between CAET score and dietary diversity (left), and food insecurity experience scale/FIES (right) along with the average values (%) for the ProSoil (PS) and comparison group of farms. A FIES score of 100% indicates households with no food insecurity.

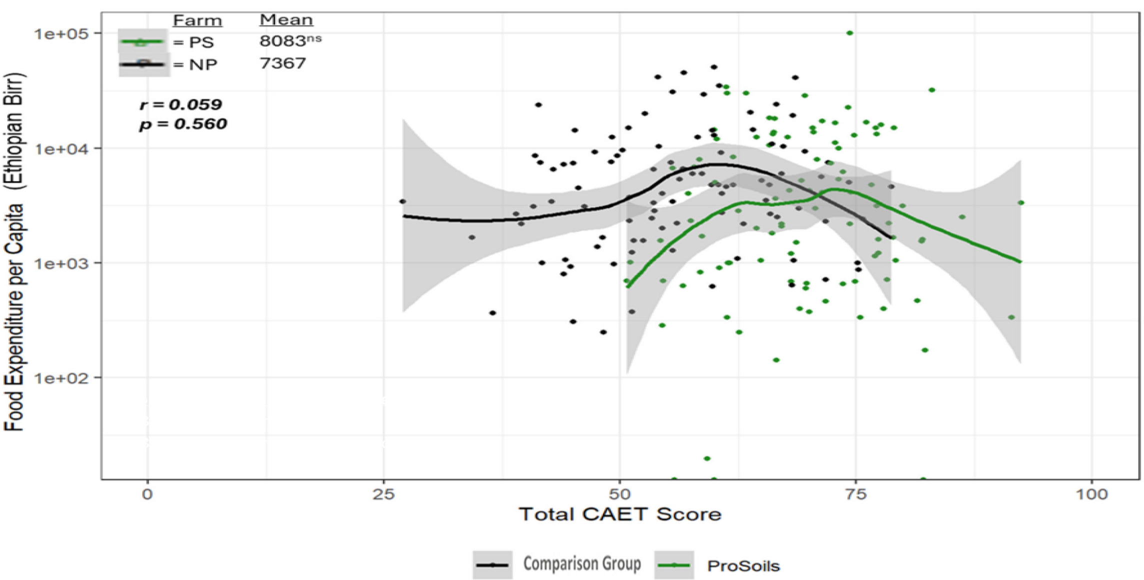


Figure 13. Correlation between level of agroecological integration (CAET score) and food expenditure per capita (Ethiopian birr) along with mean amount spent within the ProSoil (PS) and comparison group of farms

Often, this is the case when farms are in the process of diversification and not every product that the household needs is harvested on a farm. However, expenditure for food seems to decrease with an increase in agroecological integration in the long run (Figure 13).

Exposure to pesticides:

- Area of use of chemical pesticides: The mean area of chemical pesticide use was significantly higher (at $P<0.05$) for PS farms (1.6 ha) than with the comparison group (0.9 ha) (Figure 14). However, there was no correlation between the area of chemical pesticide use and total CAET score, nor other agroecology elements at PS farms. This shows that chemical pesticides are not increasingly used with agroecological integration. By contrast, there was a highly significant positive correlation between area of chemical pesticide use and the CAET score (r = 0.30**) and other agroecology elements [Diversity (r = 0.34**); Synergies (r = 0.24*); Resilience (r = 0.21*); and Co-creation and sharing of knowledge (r = 0.24*)] for the comparison group of farms/households, indicating an increase in area of chemical pesticide use.

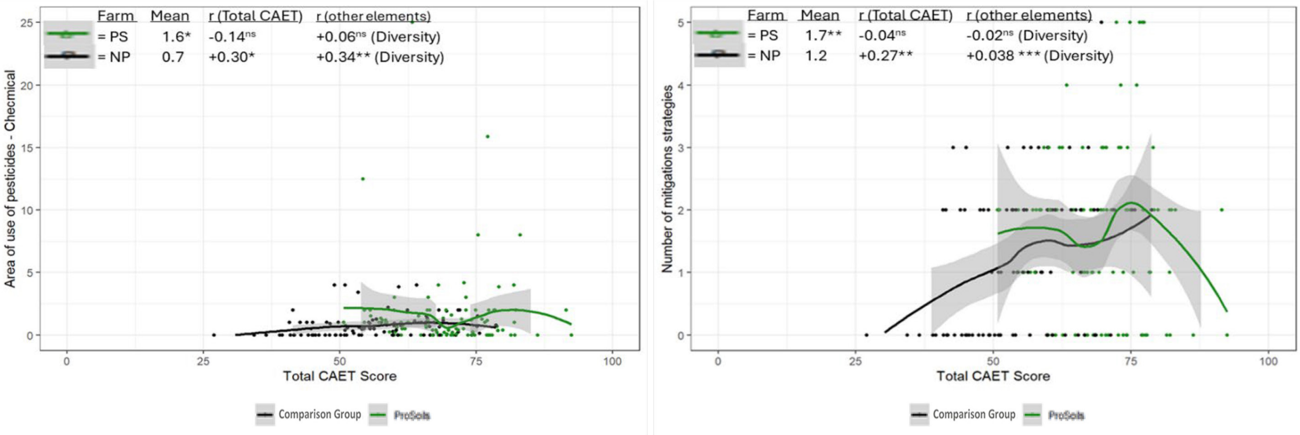


Figure 14. Correlation between CAET score and area of chemical pesticide use score (left) and number of mitigation strategies (left) within ProSoil and the comparison group of farms (* = level of statistical significance; NS =no statistical significance; r= correlation coefficient)

- Number of mitigation strategies: Compared with the NP group of farms, the mean number of mitigation strategies (use of masks, body protection, danger pre-information, safe disposal of containers) used was significantly higher (at $p<0.001$) on PS farms, which might reflect the effectiveness of the training provided by ProSoil and the collaborating public extension support staff. However, neither the total CAET score nor other elements correlated significantly with the number of mitigation strategies on the PS farms. This would be expected as the use of the mitigation strategy is a one-time training effort to be adapted by the smallholder. Besides, the area of chemical pesticide use on the PS farms did not increase with agroecological integration. On the other hand, there was a positive correlation with the number of mitigation strategies used and total CAET score ($r = 0.27^{**}$) as well as other elements (Diversity, $r = 0.38^{***}$; Synergies, $r = 0.21^{*}$; the Co-creation and sharing of knowledge, $r = 0.26^{**}$) in the NP group of farms. This corresponds well with the observed increase in area of chemical pesticide use on these farms, but this was also increasingly accompanied by the use of appropriate mitigation strategies.

3.4 Step 3 of TAPE: Participatory validation of results

Over 60 stakeholders from various institutions validated the findings from the TAPE application during a one-day participatory workshop (Woldemeskel and Getachew 2024). The participants included farmer representatives from the districts; the GIZ ProSoil district focal persons; representatives of various government institutions at different levels (federal, regional, zonal and research institutions); non-governmental organizations (NGOs – national and international); donors; and private institutions (Figure 15). In general, the participatory validation aimed to present the TAPE application results within the context of ProSoil; to evaluate and validate the agroecological transition levels of the project beneficiaries and the comparison group of farms in three selected districts (Hula, Sodo-Zuria and Walmara); to pave the way for the findings to be used in decision-making processes; and to analyse the multidimensional performance of agroecology and its impacts on the social, environmental and economic dimensions. Participants have different backgrounds and levels of understanding about the concept of agroecology and the methods used to evaluate agroecology performance. To make the process smoother and to bring about the same level of understanding among participants, participants were presented with an overview of different agroecology metrics frameworks and contexts, and were briefed on the background of ProSoil before the presentation of the TAPE application results for validation (Woldemeskel and Getachew 2024). Finally, participants had the chance to reflect on the results presented to them, to share their thoughts, and to provide their feedback and recommendations.

Figure 15. Participants at the TAPE application results validation workshop at ILRI-Ethiopia campus, April 2024, Addis Ababa, Ethiopia.

Photo by E. Woldemeskel/CIFOR-ICRAF

A holistic approach to sustainable agriculture is the tune of the day: Participants indicated that a growing population, dwindling farm size, land degradation, as well as food and nutrition insecurity are interrelated problems in Ethiopia. In the face of these problems, participants underscored the application of agroecological farming principles as essential to bringing about a sustainable food system while safeguarding environmental health. The findings from the TAPE application were presented at the workshop, indicating the agroecological transition levels of the ProSoil's group of beneficiary farms against the comparison households, while demonstrating the multidimensional performance of agroecology (economic, environmental and social dimensions) at farm level. Overall, 50% of the participants indicated that they had been involved, in one way or another, in evaluating the performance of development projects (though not exactly with the TAPE application); 32% had not been involved; and 18% did not know what agroecology or agroecological transition itself was. However, 97% of the participants were very happy with the results and the findings, finding them useful for the transformation of food systems in Ethiopia.

Need for assessment of landscape level performance: The TAPE application showed results on agroecological performance at the farm level. However, performance assessments at the landscape level are preferable (if this is available with TAPE methodology) to show impacts on a wider scale. Since unsustainable agricultural practices fundamentally affect the production environment and compromise food security, most participants (63%) felt that the integration of agroecological practices on a wider scale could achieve more in the transformation of the food system. Of all the participants, 13% would like to stick to farm-level evaluation, while 25% were unsure whether the application should be applied on a wider scale.

Co-creation and sharing of knowledge is key for the advancement of agroecology: The comparative performance of the ProSoil group of farms – where almost half of them have a CAET score greater than 70% (advanced level of agroecology) – is an encouraging sign to further the promotion of agroecology. This group had no "non-agroecological" farms compared with the 28% found with the comparison group. However, it is also noteworthy that a substantial number of farms from the comparison group were in transition and/or at advanced levels of agroecology, even though they were not beneficiaries of the ProSoil interventions. This could be due to the horizontal transfer of knowledge from the PS farms to the comparison group. Farmers in rural areas have a strong network of information exchange where new developments reach neighbourhoods through different mechanisms, including gatherings at marketplaces and social events. Ten years of the ProSoil's implementation is long enough for this information exchange, and it is possible that innovative technologies could have passed to the comparison group of farms. In this regard, partners indicated that not having baseline information at project start was an important shortcoming. The comparison group of farms that were assessed at the same time as the PS group may not provide a reliable contrast as a result of information exchange.

Support non-agroecological farms to transit to agroecology: According to the findings of the TAPE application, the integration of agroecology on most of the farms targeted in this study (even including the comparison groups) proved evident. However, a substantial number of the farms are still "non-agroecological" with extremely low CAET scores. Performance is therefore a point of concern and calls for further efforts to enhance the integration of agroecology, particularly for these "non-agroecological" farms. Participants suggested different mechanisms to promote agroecology, including the establishment of a national agroecology platform and providing incentives to farms to apply agroecological practices. The stakeholders were divided in their opinions: Forty-eight percent of the participants said that providing incentives is a good way to encourage farmers in Ethiopia to adopt agroecology practices, while 28% were not in favour. The latter group said farmers should adopt agroecology based on their realization of the potential benefits, rejecting the idea of providing special incentives because their agroecological transition would fade when this support is discontinued. Furthermore, 85% of the participants were in favour of establishing a national agroecology platform or community of practices, while 5% of them indicated that platforms of a similar nature (such as the National Watershed and Agroforestry Multistakeholder Platform) were already available, and it would be better to strengthen them than to establish new ones.

Evidence from the TAPE application is useful to guide decision makers: Almost all of the stakeholders who participated in the validation workshop (95% of the attendees) expressed satisfaction with the TAPE application and the results presented at the workshop; the evidence on the multifunctional performance of agroecology; and its relevance. Application of agroecology principles in the context of farming in Ethiopia has the potential to transform the country's food systems. However, to realize the agroecological transition of food systems in Ethiopia, more emphasis should be given to supporting activities such as advocacy, investment at the landscape level, and capacity building, according to participants. To this end, the results of the TAPE application in this study (including TAPE findings from other studies in the country) should be useful for guiding decision makers, donors and other development programmes/projects in planning and targeting new investments.

Youth are not interested in engaging in agriculture: Despite agroecology's positive impacts on the environment, the economy and job opportunities, youth are not interested in engaging in agriculture, and there is a high level of emigration, which was a point of discussion. A participant posed a series of questions, which all stakeholders supported and debated: What to do about youth motivation? We see there are job opportunities, but what can be done to create demand from youth? Give them preferential access to microfinance? Access to quality inputs in line with AE Principles (seeds, biopesticides, biofertilizers)? And how can we attract youth into agriculture? (Woldemeskel and Getachew 2024). For this, several reasons were mentioned, including the long wait required in agriculture for benefits to mature into cash (while youth seek an immediate return); the labour-intensive nature of agroecology (such as activities with composting, and the management of multiple components/diversified systems); and the lack of a conducive policy environment. While involvement in information technology-based tasks, such as value chain activities (input supply and marketing of agricultural products), may interest youth, an enabling policy environment was indicated as an important impediment. In Ethiopia, land is public and/or government property constitutionally, with farmers having only a right of use – they cannot sell or use land for collateral purposes to borrow money for agricultural development. This is often mentioned as an important problem, also in other forums, to facilitate business in the agricultural sector.

4 Conclusions and recommendations

The Measuring Agroecology and its Performance (MAP) is a collaborative project whose focus is evidence generation on the multidimensional performance of agroecology through gathering and analysing reliable and consistent data at the farm level and the assessment of agroecological transition levels using the Tool for Agroecology Performance Evaluation (TAPE). The TAPE tool represents a collaborative global methodology, developed with contributions from numerous international organizations, with FAO serving as the host. The tool has been employed in evaluating the agroecological performance of projects spearheaded by diverse entities, including GIZ.

CIFOR-ICRAF Ethiopia, along with its counterparts in Benin and Kenya, implemented TAPE, including conducting the field survey, reporting, and validating the results by presenting them to the relevant national stakeholders. As part of this task, the agroecological transition levels of smallholder farms in three districts (Hula, Sodo-Zuria and Walmara) in Ethiopia were assessed. The findings, while indicating the level of agroecology integration within the ProSoil and comparison groups of farms, demonstrated the multidimensional performance of agroecology.

With an average CAET score of 70%, the PS group of farms had significantly higher agroecological transition levels than the comparison group of farms (NP), which had an average CAET score of 55%. Overall, the TAPE analysis revealed that 82 of the 99 PS farms were either in transition to (CAET scores between 60% and 70%) or at an advanced level of agroecology (CAET scores > 70%), showing that the ProSoil intervention has a positive overall impact and contributed to the agroecological transitioning of the farms. However, from the similarity of the average CAET scores of the PS and NP groups of farms (70% vs. 55%), it could be assumed that one or both of the following had contributed to the observed result: 1. All farms at the study sites traditionally apply some form of agroecological practices in farming; or 2. There was a good level of technical knowledge transfer from the PS group of farms to the comparison groups, and the integration of agroecology is as good with the comparison group of farms. Since there is no baseline information at the ProSoil start (in 2015) and the survey was conducted at the same point in time, it is not possible to give a credible explanation. However, given the fact that a very low CAET score (as low as 20%) was detected with the comparison group and 28% of the farms were non-agroecological (scored below 50%), further investments in this group of farms would be justified to enhance the level of integration of agroecology with them.

According to the CAET scores on the 10 elements of agroecology, all the PS farms were highly significantly different ($p<0.001$) for all 10 elements, again indicating the effectiveness of the ProSoil interventions on each individual element and contributions for agroecology transitioning of the target farms. Further, the CAET values <50% detected with the NP farms, namely on Efficiency, Recycling, and Co-creation and sharing of knowledge, indicated which specific agroecological elements that future project investments (from GIZ or otherwise) should focus on to improve the situation at low-performing farms. This information would be most useful for decision makers to guide them in targeting new investments, but also for donors and development partners for planning their resources.

Even though the PS farms in all the districts consistently scored significantly higher (p < 001), with CAET scores of over 50% CAET, indicating that the PS farms were overall at a higher level of understanding and application of agroecology, the pattern of adoption/integration of agroecology in the three districts shows remarkable differences, as evidenced by the CAET scores between the PS and NP groups in the respective districts. The lowest CAET score differences of less than 10% (between PS and NP farms) were recorded for seven of the 10 elements in Walmara district, while CAET score differences of > 20% were recorded on all 10 elements in Sodo-Zuria district. Performance scores in Hula district were in between those of these two districts, and CAET score differences (between the PS and NP groups of farms) of >10% (but <20%) were recorded on eight of the 10 elements, putting Hula district in between the two districts. These details indicated regional (district) differences in adoption of the agroecological innovations and knowledge that ProSoil has introduced. Again, this provides important information for decision makers and donors in guiding decisions on regional investments in agroecology in the future.

Step 2 of TAPE measures 10 core criteria of performance under five key dimensions of sustainability, including economic, environmental and social. The overall pattern in the relationship between the variables, i.e., the various performance indicators and the total CAET scores, across the PS and comparison group, has been plotted on a number of scatter plots (Annex III, Pages 44–46), together with a moving average trendline where the 95% confidence intervals around this pattern were indicated. In addition, to explore the relationship between various performance indicators and the CAET scores (overall and each of the 10 AE elements), the Spearman's rank correlation coefficient was employed.

The overall results on core criteria of performances and patterns of distribution in the relationships between the CAET scores and the key dimensions of sustainability (economic, environmental, social, and food diversity and nutrition) across the PS and comparison group of farms generally demonstrated significant improvements (at various probability levels, from < 0.05 to <0.001, depending on the variable under consideration) in performance with increasing integration of agroecology. In the economic dimensions, a significant increase (at P<0.05) in mean total value of farm output and value added with PS farms over the comparison group has been noted. Also, the positive and significant relationship between these economic variables and total CAET score (r = 0+0.32**) and several agroecological elements, including Diversity (r = 0.50***), Resilience (r = +0.35**), and Co-creation of knowledge (r = +0.23**), showed the positive impact of agroecology practices in farming. In the environmental dimension, a significant increase in agrobiodiversity, IPM (integrated pest management) scores, and significant relationships with the CAET score (r = +047***), unequivocally demonstrated that integration of agroecology is a viable alternative for sustainability in farming in Ethiopia. As a reflection of the progress made with the economic and environmental dimensions, there were significant improvements in food diversity, household nutrition, and food security with increased integration of agroecology in farming.

While sufficient levels of employment opportunity (generally >50%) were available for women and youth, women's and youth empowerment were neither significantly different for the PS and NP groups nor did they show significant relationships with the integration of agroecology. Interestingly, despite improvements in the economic and environmental dimensions, youth emigration levels increased with the increased integration of agroecology (r = +0.22* between total CAET and youth emigration), indicating that youth do not like to engage in agriculture. This, as well as the lack of relationship between agroecological integration and women's empowerment, warrants further investigation to establish the contributing factors and to devise remedies.

The mean Soil Health Index, measured through TAPE-based assessment of 10 soil biophysical attributes, showed significant improvements under the PS farms (3.2**) and has a positive and significant relationship with the total CAET (r = 0.30**) as well as a number of agroecology elements, thus indicating the positive role of agroecological practices for soil health maintenance. However, .

this is not affirmed with the results obtained based on the LDSF, which employed lab-based soil physicochemical attributes. It is intriguing why farmer-based assessment through practically observable attributes is not substantiated scientifically through quantitative analysis. This calls for further in-depth investigation to zoom in on the design of a combined assessment method that considers farmer observation.

- PS farms are at higher levels of agroecological transition, so they provided evidence that the ProSoil intervention had a positive overall impact and contributed to the multifunctional performance of agroecology. The government should think about mainstreaming agroecology principles into farming throughout the country,
- New investment should consider filling gaps in ecological elements on which the CAET scores were low (<50 CAET), particularly Diversity, Efficiency, and Co-creation and sharing of knowledge.
- ProSoil focused its investment on important agricultural resources (e.g. soils), but investments in other areas – such as health, value chains (input supply and market access), and natural resource conservation – would bring more overall advances in the food system and should be considered equally.
- The results from the TAPE application in the context of ProSoil indicate the multidimensional performance of agroecology and call for more all-sector inclusive investment to bring about a fundamental transition to agroecology.
- Using TAPE (but also the right metrics framework), stakeholders and development partners are encouraged to evaluate their roles through an “agroecological lens,” meaning how their investments contribute to the agroecological transition and the overall transformation of food systems.
- Decision makers (at government institutions), donors and development partners should consider the TAPE evidence and results to finetune policies, and to target investment and resources.
- The results from the TAPE application in the context of ProSoil indicate the multidimensional performance of agroecology and call for more all-sector inclusive investment to bring about a fundamental transition to agroecology.

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Annexes

Annex I. Key performance 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.

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Annex 1. Continued

Group	Subgroup	Column name	Indicator name	Unit of measurement	Description
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.
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.

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Annex 1. Continued

Group	Subgroup	Column name	Indicator name	Unit of measurement	Description
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
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.

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Annex 1. Continued

Group	Subgroup	Column name	Indicator name	Unit of measurement	Description
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
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 crop varieties	Count	Total number of species and crop varieties 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

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Annex 1. Continued

Group	Subgroup	Column name	Indicator name	Unit of measurement	Description
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.
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 3 - Few aggregates that break with little pressure 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 3 Thin compacted layer, some restrictions to a penetrating wire 5 No compaction – flag can penetrate all the way into the soil

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Annex 1. Continued

Group	Subgroup	Column name	Indicator name	Unit of measurement	Description
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 3 Shallow to moderate soil – less than 3 feet (1 meter) until you reach bedrock 5 Deep soil, more than 3 feet deep
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 3 Residues are visible – they slowly decompose during the season 5 Residues are quickly decomposed, and we can see various stages of decomposition
Environment	Soil health	colour	Colour, 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 3 Light brown, odourless, and some presence of humus 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 3 Limited moisture level available for short time 5 Reasonable moisture level for a reasonable period of time

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Annex 1. 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 3 Less than 50% soil covered by residues or live cover 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 3 Evident, but low erosion signs (e.g. rill/ sheet erosion) 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 3 A few earthworms and arthropods present 5 Abundant presence of invertebrate organisms
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 3 Light to medium effervescence 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.

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Annex 1. Continued

Group	Subgroup	Column name	Indicator name	Unit of measurement	Description
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
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

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Annex 1. Continued

Group	Subgroup	Column name	Indicator name	Unit of measurement	Description
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
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

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Annex 1. Continued

Group	Subgroup	Column name	Indicator name	Unit of measurement	Description
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 1. 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 1. Continued

Group	Subgroup	Column name	Indicator name	Unit of measurement	Description
Economy	Income	intl_poverty	% of people living below poverty line	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.

The Measuring Agroecology and its Performance (MAP) project is a collaboration to generate evidence of how agroecology can contribute to societal goals. The project assessed the performance of agroecology in three districts (Hula, Sodo-Zuria and Walmara) in Ethiopia, which have been part of the GIZ global project, Soil Protection and Rehabilitation for Food Security (ProSoil), since 2015. Analysts applied Tools for Agroecology Performance Evaluation (TAPE), as well as the Characterization of Agroecological Transition (CAET) on 99 farms that participated in the global project, and on 99 non-participating farms as a control group.

Various economic performance indicators show that agroecology is effective at improving agricultural productivity, household income and livelihoods in the study locations. In addition, results show that practising agroecology might reduce costs of production input. They also showcase how agroecology can support healthy and resilient ecosystems.

Similarly, improved food security was significantly associated with the integration of agroecology, particularly with the elements of diversity, synergies and efficiency. Participating farms also showed significantly improved dietary diversity at advanced stages of agroecological transitions. Further, the percentage of children and family members in households working in agriculture correlated well with agroecology. However, no significant relationship was detected between agroecology and women and youth empowerment.

The outcomes offer valuable lessons on how technologies advanced by the GIZ project have a significant impact on the CAET elements. Additionally, results shed light on the policy and financial support needed from governments and other key players to broaden agroecological practices.

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.