FACULTY OF
BIOSCIENCE ENGINEERING

Agroecological pathways to healthy diets

Emeline Clotuche
Student number: 02100923

Promotor(s): Prof. dr. Carl Lachat ,. dr. ir. Céline Termote

Master's Dissertation submitted to Ghent University in partial fulfilment of the requirements for the degree of Master of Science in Nutrition and Food Systems

Academic year: 2023-2024

GHENT
UNIVERSITY

Copyright

Acknowledgement

First, I extend my deepest gratitude to my promotor, Prof. Dr. Carl Lachat, for his invaluable supervision of my thesis. His feedback, interesting insights into nutrition and dietary diversity, and support have greatly enriched my academic journey.

I am also immensely thankful to my Co-Promotor, Dr. ir. Cèline Termote of Bioversity International and CIAT, for providing me the opportunity to enhance my learning through data collection in Kenya. Her extensive experience and knowledge on the subject have been essential in shaping my understanding and approach.

Additionally, I must express my profound appreciation to Lilian Aluso, research assistant at Bioversity and CIAT. During my fieldwork in Vihiga County, her expertise in local projects and extensive knowledge of the area have helped immensely. I am deeply grateful for her guidance and the valuable insights she provided.

I would also like to thank all the enumerators. Their enthusiasm and experience in the field were crucial to the success of our research.

Thereby, I want to extend my gratitude to Joe Alpuerto of the Food and Agriculture Organisation for his assistance with the TAPE tool collection and analysis.

Lastly, special thanks to my family and friends for their support throughout this process. Their encouragement and belief in my abilities have been a source of strength and motivation.

Table of Contents

List of abbreviations

BMI	Body Mass Index
CAET	Characterization of the Agroecological Transition
CBO	Community-Based Organization
FAO	Food and Agriculture Organisation
FSN	Food security and nutrition
GVP	Gross value of the production
Ha	Hectare
HLPE	High Level Panel of Experts on Food Security and Nutrition
ISFAA	Intersectoral Forum on Agrobiodiversity and Agroecology
KDHS	Kenya Demographic and Health Surveys
KES	Kenyan Shilling
LSU	Livestock Unit
MDD-W	Minimum Dietary Diversity for Women
NCDs	Non-communicable diseases
SDG	Sustainable Development Goal
TAPE	Tool for Agroecology Performance Evaluation
VA	Value Added
WEAI	Women's Empowerment in Agriculture Index
WHO	World Health Organization

Figures

Tables

Abstract

This master's research on “Agroecological pathways to healthy diets” is conducted within the project “*Diverse seeds and planting materials supporting farm resilience, inclusive value chains and healthy diets in a sustainable Vihiga County food system*” implemented by the Alliance of Bioversity International and CIAT in Kenya. The objective of this research is to investigate the relationship between agroecological practices and the relationship with the diversity in diets in Vihiga county, Kenya. By using the Tool for Agroecology Performance Evaluation (TAPE) and the Minimum Dietary Diversity for Women (MDD-W) indicator, the study provided insight into how agroecology influences nutritional outcomes. Analysing the differences in the performance of agroecological elements between the intervention and control groups, showed that the intervention group performed better than the control group. Furthermore, the Characterization of the Agroecological Transition (CAET) score was used to categorize the sample. Similarly, it seemed that the higher the category score of the agroecological elements, the better they performed. While agroecological practices have been linked in the literature to increased dietary diversity, the results of this study did not indicate a significant relationship. The agroecological transition has made only modest progress, calls for continued efforts in policy-making and practical interventions.

1. Introduction

1.1 Background

The global nutrition crisis is characterized by persistent levels of malnutrition, including hunger, obesity and micronutrient deficiencies. Nearly 3.1 billion people worldwide lacked access to a nutritious diet in 2020. This is 112 million more than in 2019 due to the COVID-19 pandemic's economic effects and containment measures, which have caused inflation in consumer food prices. (Global Nutrition Report, 2020). In 2021, moderate to severe food insecurity affected 29.3% of the world's population, or 2.3 billion people, up from 25.4% prior to the COVID-19 pandemic. Meanwhile, the percentage of adults and children who are overweight or obese is rising, accounting for 40% of adults and 5.7% of children with diet-related non-communicable diseases (NCDs) (Global Nutrition Report, 2021).

Maintaining a healthy diet is critical to achieving food security goals and improving nutritional outcomes (FAO &WHO, 2023). A healthy diet is providing a sufficient and balanced intake of nutrients. Dietary diversity may have other effects on health than simply being a good source of different macro- and micronutrients and ensuring nutrient adequacy. A person's diet may be of lower quality if that person consumes a limited variety of foods or insufficient amounts of different foods (WHO, 2020).

Sustainable Development Goal (SDG) Target 2 aims to end hunger and malnutrition by ensuring year-round access to sufficient and nutritious food for all, with a particular focus on the most vulnerable, such as young children. In addition to increasing production and productivity, protecting ecosystems and strengthening capacities to adapt to climate change and extreme weather events, this goal also promotes the global adoption of resilient agricultural practices (United Nations, 2023). Sustainable healthy diets are dietary patterns that promote all dimensions of health and well-being of individuals; have low environmental pressure and impact; are accessible, affordable, safe, equitable; and culturally acceptable. These diets integrate all dimensions of sustainability to prevent adverse outcomes for people and planet (FAO & WHO, 2019).

Agroecology is increasingly recognized as a solution to the global nutrition and climate crisis and supports numerous targets of the SDGs through comprehensive practices in various areas. It addresses important issues that are in line with the goals of the 2030 Agenda, including hunger, poverty, inequality, climate change, biodiversity conservation, and the expansion of nutritional options. Agroecology takes a comprehensive approach, placing equal emphasis on environmental, social, and economic sustainability. By improving the lives of women, youth, indigenous communities, and

smallholder farmers, this approach promotes a balance between the welfare of people and the environment (FAO, 2018a).

Despite the fact that agroecology is gaining interest from different stakeholders, more evidence is needed on the association between agroecological practices and more diverse and healthier diets (Kerr et al., 2021). The Tool for Agroecology Performance Evaluation (TAPE) tool was created by the Food and Agriculture Organization (FAO) to characterize the agroecological transition. TAPE is based on the FAO's ten agroecology elements, which take into account different dimensions of agroecology, and assesses the multifaceted performance of agricultural systems in various contexts and scales. Gathering data on the frequency and intensity of agroecological practices and evaluating the effectiveness of agroecological systems in relation to sustainability's various dimensions are the main goals (Mottet et al., 2020). The Minimum Dietary Diversity for Women (MDD-W) is an indicator that is used to assess diet diversity and is used in the nutrition dimension of the TAPE tool. It evaluates whether women aged 15 to 49 have consumed at least five out of ten specified food groups during the preceding 24 hours. This MDD-W indicator is included in the TAPE tool as a listed-based 24h recall (FAO, 2019; 2021).

1.2 Objectives of the research

The aim of this research is to investigate the relationship between agroecological practices and the relationship with the dietary diversity of the target population of 240 households. This research was conducted in Western Kenya, Vihiga County, as part of a project by the Alliance of Bioversity and CIAT. This project promoted agroecology through interventions. The households' agroecological transitions were assessed using the TAPE tool, and the MDD-W was calculated through an additional open 24-hour recall.

Research questions:

1. Are there differences in the results of the ten agroecology elements across the defined CAET in the target population?
2. Are there differences in the results of the ten agroecology elements across the intervention group and control group in the target population?
3. Are there differences in the performance of the dimensions of sustainability across the defined CAET categories in the target population?
4. Is there a relationship between the agroecological transition and healthy diets?
5. Is the MDD-W indicator the right dietary indicator to make this link with agroecology?

2. Literature review

2.1. Introduction to agroecology

2.1.1. Evolution and definitions of agroecology

2.1.1.1 Origin of agroecology

The definition of agroecology has transformed over the decades. The term 'Agroecology' originated in the 1930s in scientific literature, initially referring to the scientific examination of the biological interactions between individual crops and various elements within the agroecosystem. Since the 1960s, there has been a significant expansion in the scope and focus of agroecology. The analysis has shifted from examining individual plots or farms to encompass entire agroecosystems and even the broader food system. Moreover, its focus has evolved beyond ecological and agronomic analyses to include an interdisciplinary approach that incorporates socio-economic and political dimensions (Wezel et al., 2009).

2.1.1.2 Agroecology as a scientific discipline

Since the 1980s, agroecology has served as a conceptual framework, playing an essential role in advocating for agroecological practices (Wezel et al., 2009). By the 1990s, agroecology had established itself as a scientific discipline with a well-defined conceptual framework and methodology for comprehensively studying agroecosystems, integrating both human and environmental components (Gliessman, 2014). This perspective considers an agricultural production area as a complex system where ecological processes coexist with various human activities, encompassing not only economic aspects but also social and cultural dimensions. In this context, agroecology focuses on understanding the dynamic interrelationships between these elements (Altieri, 1995).

2.1.1.3 Global perspective and framework

Since the 2000s, agroecology has shifted from a focus on individual fields or agroecosystems to a broader approach encompassing the entire food system. This evolution acknowledges the global interconnectivity of food production, distribution, and consumption. The agroecological framework currently adopts a comprehensive perspective of the global network of the food system (Gliessman, 2007). In recent years, agroecology has gained interest and is being actively promoted and discussed across different platforms. Different intergovernmental organizations, like the FAO and authoritative scientific bodies like the High-Level Panel of Experts on Food Security and Nutrition (HLPE), have been essential in establishing globally accepted definitions and frameworks (Silici, 2014).

At present, the term 'Agroecology' still has different interpretations. This term appears globally and is adjusted to the specific priorities of countries or institutions (HLPE, 2019). The HLPE 2019 report concludes that the shared objective among all definitions is the promotion of sustainable food systems. HLPE formulated a definition that associates agroecology with sustainable food systems to ensure food security and nutrition (FSN). The HLPE's definition of agroecology is as follows:

"Agroecological approaches favour the use of natural processes, limit the use of purchased inputs, promote closed cycles with minimal negative externalities and stress the importance of local knowledge and participatory processes that develop knowledge and practice through experience, as well as more conventional scientific methods and address social inequalities. Agroecological approaches recognize that agrifood systems are coupled social–ecological systems from food production to consumption and involve science, practice and a social movement, as well as their holistic integration, to address food and nutrition security" (HLPE, 2019).

2.1.2. Agroecological frameworks

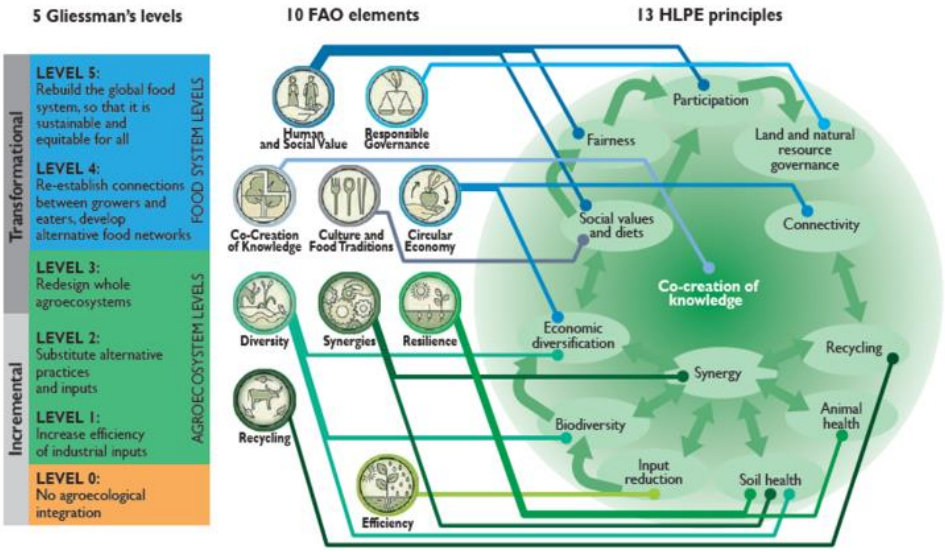


Figure 1: *Linking FAO's ten elements, Gliesmann's five levels of food system transformation and the thirteen HLPE principles (Atta-Krah et al., 2021).*

During the last century, different sets of agroecological principles were developed. Agroecology is now associated with a set of principles guiding agriculture and food systems, covering both agricultural and ecological management. Additionally, socio-economic, cultural, and political principles have been integrated. These broader principles originated from social movement initiatives actively engaged in agroecology and only recently gained acknowledgement in the literature. The HLPE compiled a comprehensive report to harmonize the diverse perspectives on agroecology and developed thirteen principles specific to agroecology (HLPE, 2019). The FAO outlined the ten elements of agroecology as a

guiding framework for transitioning into agroecological practices (FAO, 2018b). Instead of competing with each other, the two parallel processes, FAO and HLPE, have mutually influenced each other despite their somewhat different objectives. The HLPE report focused on establishing a scientific foundation and generated recommendations for policymakers. In contrast, the FAO elements are created to organize and implement support for member countries in agroecology, spanning from practical application to policy formulation. Each element aligns with one or more of the principles as shown in **Figure 1** (Wezel et al., 2020).

2.1.2.1. The thirteen principles of agroecology

***Figure 2**: The operating principle of sustainable food systems is linked to the thirteen agroecological principles. The key levels for a successful transition are shown in the inner circles of the figure (Biovision, 2019).*

The HLPE established thirteen principles linked to the operational principle of sustainable food systems to achieve FSN (HLPE, 2019). These operational principles focus on improving resource efficiency, strengthening resilience, and ensuring secure social equity. They cover the agroecological principles including biodiversity, synergies, economic diversification, animal health, soil health, input reduction, recycling, participation, land and natural resource governance, connectivity, fairness, social values and diets, and co-creation of knowledge (HLPE, 2016) (**Figure 2**). Many agroecological principles support more than one operational principle, even though each one directly corresponds to a single operational principle. This report was designed to guide policy discussions and understanding of how agroecology could help to achieve sustainable food systems (HLPE, 2019).

2.1.2.2. Ten elements of agroecology

According to the FAO, ten interconnected and interdependent elements define the framework of agroecology, including 'Diversity', 'Synergies', 'Recycling', 'Efficiency', 'Resilience', 'Co-creation and Sharing of knowledge', 'Human and Social values', 'Culture and Food traditions', 'Circular and Solidarity economy', and 'Responsible governance' (FAO, 2018b) (**Figure 3**). They play a crucial role in promoting an inclusive approach of agroecology, avoiding biases towards specific definitions, stakeholders, or regions. They serve as a flexible framework for entities contributing to the promotion of agroecology and to offer an analytical tool. These elements can be utilized by policymakers, practitioners, and stakeholders in the planning, management, and evaluation of agroecological transitions. These ten elements hence facilitate the identification of areas for exploration, analysis, and the examination of plausible theories that drive transformative change towards sustainable agriculture and food systems (Barrios et al., 2020).

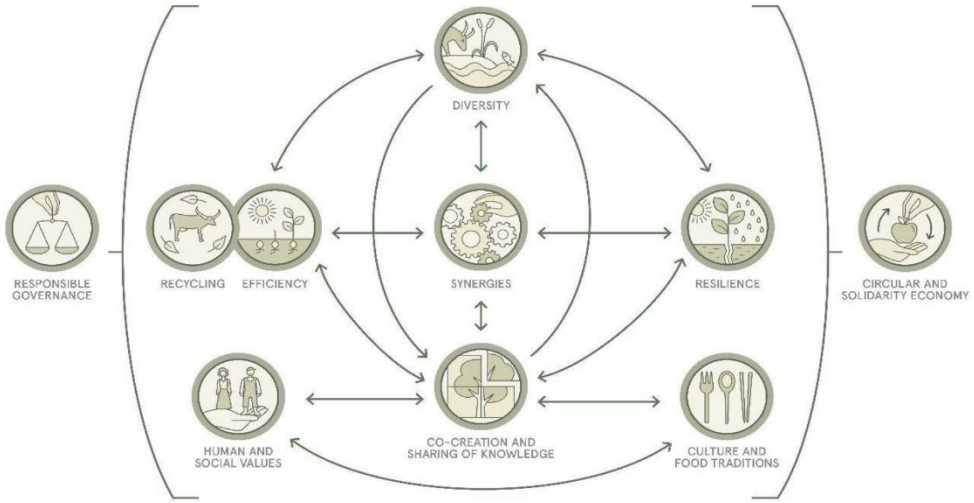


Figure 3: *Ten elements of agroecology (FAO, 2018b).*

The ten elements are organized according to their fundamental functions and the inferences derived from these elements. The elements driving diversification are 'Diversity' and 'Co-creation and Sharing of knowledge'. These constitute the foundation of the innovation characteristic of agroecological systems. Ultimately, they aim to create the element of 'Synergies'. Further, the elements of 'Efficiency' and 'Resilience' naturally manifest in systems built upon the preceding three elements, with a central focus on the practice of 'Recycling'. Additionally, there are the elements of 'Human and Social values' and 'Culture and Food traditions', offering insights into the contextual characteristics of these systems. Lastly, the elements 'Responsible governance' and 'Circular and Solidarity economy' not only indicate the supportive framework but also represent broader aspirations (FAO, 2018b) (**Figure 3**).

2.1.3. Agroecology: A pathway to sustainable food systems

Agroecology is a method to transform food systems into equitable and sustainable food systems. It plays a significant role in achieving the SDGs (FAO, 2018a). Gliessman and Wezel developed different frameworks to illustrate agroecological transitions (Gliessman, 2016; Wezel et al., 2020).

2.1.3.1. The agroecological transition pathways framework of Gliessman

The framework for agroecological transition pathways designed by Gliessman, includes five different levels (**Figure 1**). Within this framework, the transitions to agroecology have been conceptualized from the adoption of farming practices and cropping systems to a more complex and comprehensive food system redesign. The initial three levels describe the practical measures farmers can implement on their farms to shift away from conventional agroecosystems. Additionally, two further levels extend the scope beyond individual farms to encompass the broader food system and societies in which these farms are integrated. These five levels can function as a roadmap, providing a stepwise guide for transforming the entire global food system (Gliessman, 2007; 2016).

2.1.3.2. The agroecological transition pathways framework of Wezel

Wezel et al. (2020) indicated four key pathways in the FAO's ten elements of agroecology, to establish agroecological transition pathways towards sustainable food and agriculture systems (**Figure 4**).

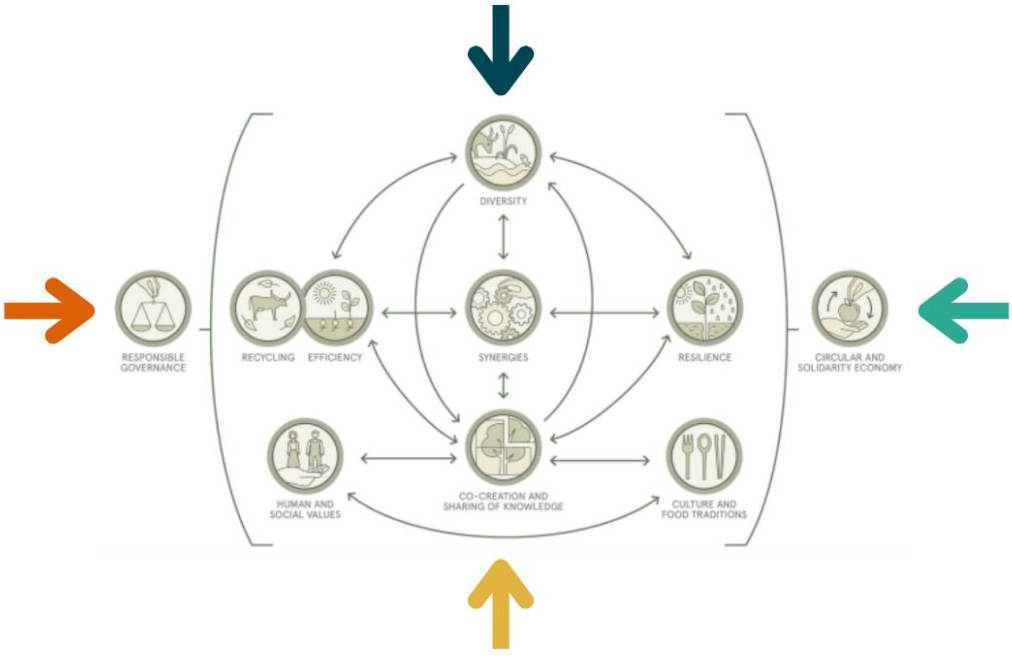


Figure 4: *Four key entry points in FAO's ten elements of agroecology framework to build transformative change pathways towards sustainable food and agricultural systems (Adapted from Wezel et al. 2020).*

Diversity element

The first key pathway highlights the importance of diversification, which holds a central role in addressing challenges associated with climate change and nutrition. Variations in the utilization and management of plant and animal diversity can have a substantial influence on the adaptability of agricultural systems to climate change and their contribution to nutritious diets (Snapp et al., 2010). Compared to traditional farming practices, diverse agroecological approaches have the ability to conserve and increase wild and domesticated biodiversity by up to 30 percent (FAO, 2018a). Implementing economic diversification can have a positive impact on food security and nutrition. By increasing the diversity of on-farm incomes, financial independence will improve, along with an increased resilience to price volatility (Kanmennang et al., 2017).

Circular and solidarity economy element

The second key pathway emphasizes that changes in food consumption patterns have a profound impact on markets at various scales. Transforming consumption patterns toward nutritious and healthy diets can significantly influence both value chains and markets. This emphasises the interconnectivity of human health and environmental sustainability (Caron et al., 2018). To facilitate these transitions, adjustments on the supply side are essential. Implementing recycling initiatives, promoting shorter food circuits, and prioritizing local markets and economic development contribute to the resilience of rural communities (Schipanski et al., 2016). These strategies have proven their ability to boost and sustain incomes for food producers, while also ensuring fair prices for consumers (Feliciano, 2019). Globally, agroecological approaches have demonstrated the potential to enhance farmers' income by up to 30 percent. This is achieved through strategies such as diversification, reducing external inputs, and exploring alternative marketing channels (FAO, 2018a).

Co-creation and sharing of knowledge element

The third key pathway shows the fundamental importance of promoting formal and non-formal education across all levels to facilitate agroecological transitions, by contributing to inclusive initiatives that engage diverse local stakeholders, with particular emphasis on women and youth (Anderson et al., 2019). This not only serves to raise awareness but also encourages the effective integration of knowledge into action (Clark et al., 2016). The process of co-creation of agroecological knowledge is transdisciplinary and generates new insights and transformative change (Gliessman, 2018).

Responsible governance element

The implementation of transparent, accountable, and inclusive governance mechanisms represents the final key pathway which is establishing responsible governance. These mechanisms are important to create an enabling environment that facilitates producers in their transition toward agroecological concepts, principles, and practices (FAO, 2012). As an illustration, ensuring equal access to land and natural resources is crucial for achieving social justice. Furthermore, it provides a powerful incentive for making sustained investments essential to safeguard soil, biodiversity, and ecosystem services over the long term (Anderson et al., 2019).

2.1.4. Assessing performance of agroecology

There is need for a standardized protocol to evaluate whether a practice, project, investment, business case, or police can be qualified as agroecological. Measuring agroecology can be a very effective way to break down the complexity into more concrete indicators. Additionally, it is essential to develop methods that accurately reflect the economic, environmental, and social benefits generated by agroecological farming systems. This will facilitate equitable comparisons between agroecology and its alternatives, ensuring a fair evaluation framework (Geck et al., 2023).

2.1.4.1. TAPE as a tool to assess the performance of agroecology.

The FAO developed the TAPE tool to assess the multidimensional performance of agricultural systems at different scales and in different contexts. TAPE is based on a review of already existing frameworks to assess agroecology. The central objective is to assemble evidence regarding the prevalence and intensity of agroecological practices, along with assessing the performance of agroecological systems across the dimensions of sustainability (Mottet et al., 2020). The design of the tool ensures simplicity and requires minimal training and data inputs (FAO, 2019). Currently, TAPE has already been applied on more than 5000 farms across 40 countries, with a particular focus on Sub-Saharan Africa (Mottet et al., 2023).

2.1.4.2. Four Steps of TAPE

The tool is designed for diverse applications, ranging from project monitoring and regional assessments to comparative analysis, across various geographical contexts. The tool follows a stepwise process at the household level and can be used to collect data at community and territorial level (Mottet et al., 2020). The four-step procedure utilized in TAPE is summarized in **Figure 5**.

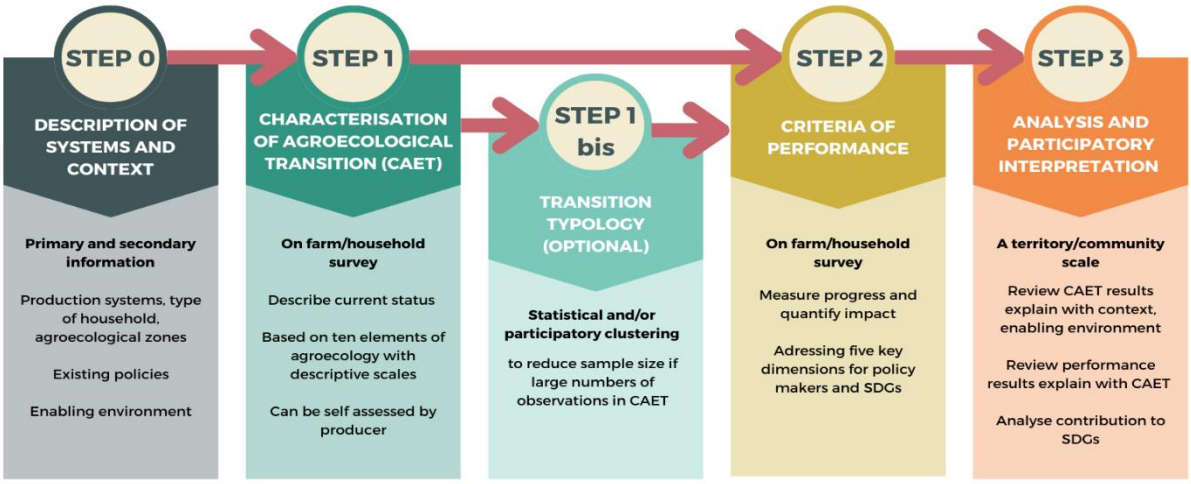


Figure 5: The analytic framework of Tool for Agroecology Performance Evaluation (TAPE), step by step (Adapted from FAO, 2019).

STEP 0

Step 0 is an introductory step that precedes the assessment of the agroecological transition. It entails providing a detailed description of the context in which agricultural holdings operate, taking into account economic, environmental, and social factors. During this initial step, various aspects are examined, including the physical characteristics of the area, land ownership regulations, regional production systems, etc. (FAO, 2019) (**Appendix A**).

STEP 1

Step 1 focuses on the CAET within agricultural systems. This characterization is based on the ten elements of agroecology adopted by the FAO (FAO, 2018b). These ten elements serve as criteria to establish 36 semi-quantitative indices, which are presented as descriptive scales featuring scores ranging from zero to four (FAO, 2019). For each of these elements, a set of closed-ended questions, usually three or four questions, are asked. Respondents are provided with five answer options to choose from for each question. Each answer correlates to a score, starting at zero points when no agroecological transition has occurred, up to four points when the element has fully undergone an agroecological transition. Once the CAET questions are completed, the scores for each element are calculated (FAO, 2019) (**Appendix B**).

STEP 1 Bis (Optional)

In cases where many evaluations are conducted using the CAET, and these occur within a similar spatial setting, the variances often show significant homogeneity. In such situations, it may be advisable or necessary to select a subset of systems or case studies. This selection should be made before proceeding to the performance criteria in step 2 (FAO, 2019).

STEP 2

Step 2 aims to systematically document the multiple outcomes of agroecology. This approach stands in contrast to the more limited scope often observed in conventional agricultural research, which tends to concentrate on singular outcomes like crop yields. During this step, the focus is on assessing the performance of farms or households across five dimensions that have been identified as essential for advancing SDGs within the agriculture and food systems domain (**Table 1**). Ten core criteria represent the essential elements that must be consistently evaluated to produce comprehensive evidence regarding multidimensional performance (Mottet et al., 2020) (**Appendix C**)**.**

All questions of step 2 must be answered by men and women to comply with the prescriptions of the SDG indicators, which require data disaggregated by gender. For the section on 'women's empowerment', the questions need to be conducted only with the main woman in the household without the presence of a man in a safe environment (FAO, 2019) (For additional details, see **Appendix D**).

Table 1: Key dimensions and ten criteria Step 2 (FAO, 2019).

Main dimensions	***Core criteria of performance***	***SDG-indicators***
Governance	Secure land tenure	1, 2, 5
Economy	Productivity	2
	Income	1, 2, 10
	Value added	10
Health & nutrition	Exposure to pesticides	3
	Dietary diversity	2
Society & culture	Women's empowerment	2, 5
	Youth employment opportunity	8
Environment	Agricultural biodiversity	2, 15
	Soil health	2, 15

2.1.5. Policies for agroecology in Kenya

In Kenya, there is no specific policy addressing agroecology. Agroecological farming is given limited attention in agricultural policies, and related activities are indirectly referenced. Government institutions have primarily emphasized industrial agriculture in their agricultural education and training programs, although there has been a recent introduction of fundamental agroecological principles, although the term 'agroecology' is not explicitly mentioned (AFSA, 2020). Currently, there is no certification available that specifically recognizes the implementation of agroecological practices (Paracchini et al., 2022). However, organic certification is available in Kenya and organic farmers are represented by the Kenya Organic Agriculture Network (United Nations, 2008). The Intersectoral Forum on Agrobiodiversity and Agroecology (IFSAA), led by the Ministry of Agriculture, Livestock, and Fisheries, is committed to enhancing agrobiodiversity and agroecology at national level. It is evaluated, updated, and devised new policies, strategies, and laws to encourage participation from various sectors including government, private entities, academia and farmer groups. Key activities of the ISFAA include reviewing and refining relevant policies and laws, monitoring their implementation, organizing policy discussions to connect stakeholders with policymakers, managing a database on policy status, and producing policy briefs and annual reports to advocate and guide agroecological practices (IFSAA, 2024).

The Murang'a County Government has enacted the Murang'a Agroecology Policy 2022-2032 and the Murang'a County Agroecology Development Act 2022, making it the first of its kind in Kenya. The act encourages the use of organic farming practices and the production of organic products, aiming to promote sustainable agricultural practices in the county. The policy and act seek to facilitate the development, promotion, and regulation of the organic food industry in the county, with a focus on sustainable and climate-smart farming practices such as crop diversification, soil conservation, and the use of biofertilizers and biopesticides. The county government aims to become a leading county in sustainable agricultural production, food security, food safety, green products trade, and marketing over the next years (Omwenga & Munyaka, 2023).

Vihiga county has also developed a proposal for an agroecology policy. This policy, which aims to promote the adoption of agroecological practices to enhance the conservation of agrobiodiversity, is now ready for public participation before its submission to the Parliament (Alliance of Bioversity International and CIAT, 2023).

2.2. Healthy diets in Kenya

2.2.1. Diets in Kenya

2.2.1.1. Nutrition situation in Kenya

In Kenya, the triple burden of malnutrition is a significant concern, including overnutrition, undernutrition and micronutrient deficiencies. As reported by the Ministry of Health in Kenya (2017), there is a growing prevalence of unhealthy eating patterns within the population. The 2022 Kenya Demographic and Health Surveys (KDHS) indicate significant changes in the nutritional status of women over the years. From 1993, the percentage of women who were overweight or obese rose from 15% to 45%. Conversely, the percentage of underweight women decreased from 10% to 7%.

More recently, in 2022, 28% of women aged 20-49 were classified as having overweight, marking a 5% increase from 2014. During the same period, the obesity rate increased from 10% to 17%, while the proportion of underweight women dropped from 9% to 7%. The evaluation of overnutrition in adults is conducted using the Body Mass Index (BMI). Individuals with a BMI of 25 kg/m^2 or more are considered overweight, those with a BMI of 30s kg/m^2 or more are considered obese, and a BMI below 18s kg/m^2 (KDHS, 2022). The rise in obesity prevalence among women can be attributed to rapid urbanization and various contributing factors. This includes shifts in dietary habits resulting from the widespread presence of supermarkets and fast-food restaurants, changes in lifestyles marked by decreased physical activity and the adoption of unhealthy eating practices, as well as the use of hormonal contraception methods (Mkuu et al., 2018).

NCDs are a growing public health concern in Kenya, accounting for over 50% of the hospital admissions and deaths. High blood pressure is prevalent among adults, and cancer stands out as a significant cause of mortality. Unhealthy diet patterns and insufficient physical activity present significant challenges in Kenya, where a considerable portion of adults falls short of meeting the World Health Organisation (WHO) recommended guidelines. Only 5% of adults aged 18-69 succeed in incorporating the WHO-recommended five servings of fruits and/or vegetables into their daily diet. Specifically, the average consumption of fruits is limited to 2.4 days per week, while vegetables are consumed five days per week. Additionally, about 20% of individuals routinely include salt or salty sauce in their meals, and 83.9 % frequently add sugar when cooking or preparing beverages at home. (Ministry of Health, 2015).

Malnutrition can occur due to insufficient overall nutrient intake or an excess of specific nutrients. The absence a single vitamin or mineral may result in serious health consequences, and an overabundance of nutrients can also lead to problems. Maintaining a balanced nutrient intake is essential to supporting the body's functions and tissues (Hickson et al., 2018).

2.2.2. Socioeconomic factors and healthy diets

Healthier dietary patterns are typically found in households that meet certain determinants. These include households with a higher socioeconomic status, those located in rural areas, households with children under five, those led by a female, and households where the head has at least a secondary education. Next, households with heads who are married, or cohabiting are more likely to maintain a healthier diet (Mohamed et al., 2021). Women are more vulnerable to undernutrition and micronutrient deficiencies, particularly due to high nutritional requirements during pregnancy and lactation. Additionally, gender inequalities in poverty contribute to these nutritional challenges (Delisle, 2008).

In urban areas, 5% of women are considered underweight, whereas in rural areas it is 9%. In terms of obesity, 53% of women aged 20-49 in urban areas are overweight or obese, compared to 39% in rural areas. Comparatively, 23% of women with no education are low BMI, against 6% of those with more than a secondary education. Obesity affects 26% of uneducated women aged 20-49 years, while 50% of those with more than a secondary education are overweight or obese (KDHS, 2022).

In terms of dietary diversity, compared to 43% of women in rural areas, 56% of women in urban areas met the minimum of five food groups of MDD-W. Dietary diversity consumption increases with educational attainment: only 20% of women with no education achieve MDD-W, compared to 67% of those with more than secondary education. Additionally, the consumption of unhealthy foods also rises with educational level, from 14% among women with no education to 42% among those with advanced education (KDHS, 2022).

2.2.3. Staple Foods and Common Dishes

In Kenya, traditional food habits have long dominated the diets, there is a noticeable rise in modern lifestyles accompanied by less nutritious dietary choices (Mohanja, 2014). Maize is the predominant cereal crop in Kenya, supplying more than one-third of the country's energy intake (Kirimi et al., 2011). The preferred choice for many Kenyans is white corn flour, used to make ugali, a thick maize porridge commonly consumed daily. Ugali is typically eaten with a side of vegetables or meat sauce, or with fermented milk. On average, an individual consumes 88 kg of maize products annually. The second most important staple food is wheat, comprising 17% of staple food consumption. Further, beans are

also an important source of calories and contribute 5% of the total calories of the national diet. Other commonly consumed foods include potatoes, plantains, and rice (Mohanja, 2014). In addition to ugali, there are also other common dishes such as Githeri, a combination of boiled maize and beans; Mukimo, a mash of potatoes with vegetables, maize, and beans; Pilau, a seasoned preparation of cooked chicken and rice; and Irio, a mix of boiled maize, beans, vegetables, and potatoes. The diet also includes essentials like bread, milk, and vegetables (FAO, 2005). The traditional leafy vegetables in Kenya are African nightshade (*Solanum villosum/scabrum L.*), cowpea leaves (*Vigna unguiculata L.*), amaranth (*Amaranthus blitum L.*), spiderplant (*Cleome gynandra L.*), slender leaf (*Crotalaria ochroleuca G.Don/brevidens Benth.)*, jute mallow (*Corchorus olitorius L./tricularis L.) and* Pumpkin leaves (*Cucurbita pepo L.*) (Ngigi et al., 2023).

2.2.4. Kenya's Dietary and physical activity Guidelines

The Kenyan Ministry of Health formulated the National Guidelines for Healthy Diets and Physical Activity, through the Nutrition and Dietetics Unit. These guidelines are designed to encourage healthy dietary practices and active lifestyles as preventive measures, addressing the triple burden of malnutrition and NCDs associated with diet and insufficient physical activity. The guidelines emphasize the importance of consuming a balanced and nutritious diet, rich in fruits, vegetables, whole grains, lean proteins, and healthy fats. They also advocate for regular physical activity. These guidelines aim to educate and empower individuals to make informed choices about their health, encouraging them to adopt healthy eating habits and engage in regular physical activity. The guidelines also highlight the need for policymakers, program designers, health practitioners, educators, and other stakeholders to collaborate and promote healthy diets and physical activity for the benefit of the entire population. (Ministry of Health, 2017). The Government of Kenya and the FAO published a recipe book for common mixed dishes with their nutrient values (FAO & Government of Kenya, 2018).

2.2.5. Dietary intake and healthy outcomes

The importance of a diverse diet is fundamental to a nutritious and high-quality eating pattern. No individual food item can supply all the essential nutrients required to sustain optimal health (Hawk, 2006). A balanced diet should include a variety of whole, minimally processed foods, such as fruits, vegetables, whole grains, legumes, lean proteins, and healthy fats. Eating at least 400g (five portions) of fruits and vegetables per day can reduce the risk of NCDs and ensure adequate dietary fibre intake. Limiting saturated and trans fats, free sugars, and sodium is also important for maintaining cardiovascular health (WHO, 2003).

2.2.5.1. Measuring dietary intake

While various methods exist to assess individual dietary intake (Gibson et al., 2017), there is a growing demand for simple and feasible proxy indicators that accurately reflect both micronutrient adequacy and overall diet quality (IFPRI, 2014). Many of these methods require highly skilled enumerators and involve significant resources for data collection, processing, and analysis. Additionally, comprehensive food composition tables are often essential for many dietary assessment methods. The MDD-W, developed by the FAO, represents a promising approach to evaluate dietary intake (Hanley-Cook, 2020).

2.2.5.2. Minimum Dietary Diversity for Women

MDD-W is a population-level indicator of diet diversity This dichotomous indicator will assess whether or not women between 15 and 49 years consumed at least five out of ten defined food groups the previous 24 hours. These food groups are the following ten groups: grains, white roots, tubers, and plantains; pulses (beans, peas, and lentils); nuts and seeds; milk and dairy products; meat, poultry, fish; eggs; dark green leafy vegetables; other vitamin A-rich fruits and vegetables; other vegetables; other fruits. A food group can only be counted toward MDD-W if fifteen grams or more is consumed. The design of MDD-W focuses on simplifying data requirements to indicate the consumption or non-consumption of food groups, eliminating the need for quantity details. This indicator is also easy to use and interpret, while also being cost-effective. Moreover, it minimizes the workload for enumerators and can be integrated into large-scale surveys, existing data collection platforms, and monitoring frameworks (FAO, 2021). In Kenya, 49% of the women met the MDD-W criteria (KDHS, 2022).

2.3. Pathways to healthy diets through agroecology

Agroecology positively impacts nutritional outcomes, particularly in low-income countries. Several studies found evidence of improved FSN in households that adopt agroecological practices. (Kerr et al., 2021). For instance, in a study in the Ecuadorian highlands, farmers practising agroecology demonstrated enhanced nutrient adequacy and dietary diversity compared to neighbouring farmers practising conventional farming (Deaconu et al., 2021).

Nutrition is recognized as a critical outcome and driver of agroecological practices, with the potential to transform the entire food system. The core principles of agroecology, including, input reduction, biodiversity, economic diversification, social values and diets, fairness, connectivity, and participation, all directly contribute to improve nutrition. The other principles of agroecology have an indirect influence on nutrition (Wezel et al., 2020) (**Figure 6**).

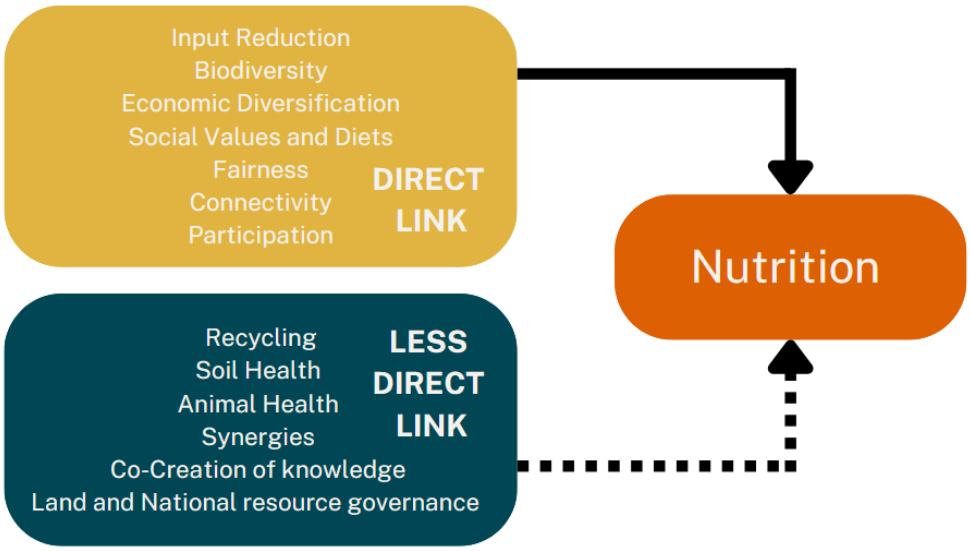


Figure 6: *The thirteen principles of agroecology and their pathways to nutrition. Solid line: principles have a direct link with nutrition. Dotted line: principles have a less direct link with nutrition (Adapted from van Zutphen et al., 2022).*

2.3.1. Agricultural impact on nutritional outcomes

Agriculture impacts nutrition outcomes in several interconnected ways. Agriculture provides as a direct source of food, allowing households to increase the availability and access to diverse foods through their own production (Koppmair et al., 2017). Second, agriculture acts as a significant source of income, either through wages earned by agricultural workers or profits from the marketing of agricultural commodities. This increased income allows households to afford a wider range of food products (Ruel & Alderman, 2013).

There is a positive relation between the diversity of agricultural production and the diversity of diets, which directly contributes to nutrition adequacy (Deaconu et al., 2021). Agroecological practices encompass a range of techniques that contribute to improved nutrition. Wezel et al. (2020) identified several of these techniques, including crop diversification, intercropping, agroforestry and soil management measures. Agroforestry, in particular, which combines tree planting with crop and livestock farming, serves as a multifaceted approach to enhance dietary variety. This method introduces a range of new fruits and vegetables, produces fodder to support animal husbandry, and creates extra income sources for purchasing a diverse selection of food. Moreover, agroforestry aids small-scale farmers in adjusting to climate change. It strengthens their ability to withstand disruptions in food security and offers various means for income generation, thereby promoting resilience and sustainability in agriculture (Duffy et al., 2021). Adopting agroecological soil management practices has multiple advantages for farmers. One of the advantages is the enhanced resilience of the crops to climate related shocks (Bliss, 2017). Additionally, farm productivity increases when these are

implemented (Nyantakyi-Frimpong et al., 2016). Furthermore, according to a study among Kenyan farmers who implemented soil management practices not only had better dietary outcomes but also earned the highest income from livestock. Additionally, they were better engaged in social networks, indicating a strong link between effective agricultural practices and broader socio-economic benefits (Kamau et al, 2018).

Implementing agroecological soil management practices such as incorporating compost, crop residues, and intercropping with legumes leads to a reduction in the use of synthetic fertilizers. This reduction has a positive impact on nutrition. Furthermore, reducing the use of these costly inputs results in income redistribution and an augmentation in budget allocation toward food spending, thereby enhancing both food security and dietary quality (Madsen, 2022).

However, this is not always the case. Additional research shows that the benefits of market access for dietary diversity frequently outweigh those of greater production diversity. Furthermore, the contribution of agriculture diversity to household nutrition may be diminished by market transactions. According to these results, increasing agriculture diversity is not always the best way to improve dietary diversity in smallholder households, and it is not a goal in itself (Sibhatu et al., 2015).

2.3.2. Impact of economic diversification on the nutrition outcomes

By diversifying economic activities on-farm, there is potential for increased financial independence and resilience against the unpredictability of market prices and the effects of climate change. This income diversification on farms plays a crucial role in maintaining consistent access to food and provides a safeguard against various economic and environmental challenges (Kangmennaang, 2017).

Moreover, national and international agricultural policies have a significant influence on trends in food prices. The price of both food and non-food crops is influenced by a variety of supply and demand factors, which are influenced by these policies. The resulting prices have an impact on households' financial health, especially if they are net food sellers or buyers, which in turn affects their ability to purchase food and how they manage their budgets (Ruel & Alderman, 2013).

2.3.3. Investments in social and human capital

There are significant consequences associated with women working in agriculture. By giving them access to resources and the ability to make decisions, it can improve women's social status and sense of empowerment, especially when it comes to issues as intra-household food distribution, health, and

care. Women who work in agriculture also have to manage their time better, juggling caregiving and household duties with activities that generate income (Ruel & Alderman, 2013).

Investing in social and human capital, including nutrition education and gender equality, can have long-term positive effects even without financial capital (Berti et al., 2004). Agroecological and diversified systems also provides farmers an opportunity to exchange food and other products within their communities. Furthermore, it builds and strengthens social relations that are often integral to FSN. (Deaconu et al., 2021).

3. Material and methods

3.1 Study Area

The study was carried out in Vihiga County, located in Western Kenya, in the Lake Victoria Basin. Vihiga County is divided into five constituencies or sub-counties namely Luanda, Sabatia, Emuhaya, Hamisi and Vihiga and subdivided into thirteen divisions, comprising 41 locations and 140 sub-locations (County Government of Vihiga, 2023) (**Figure 7**).

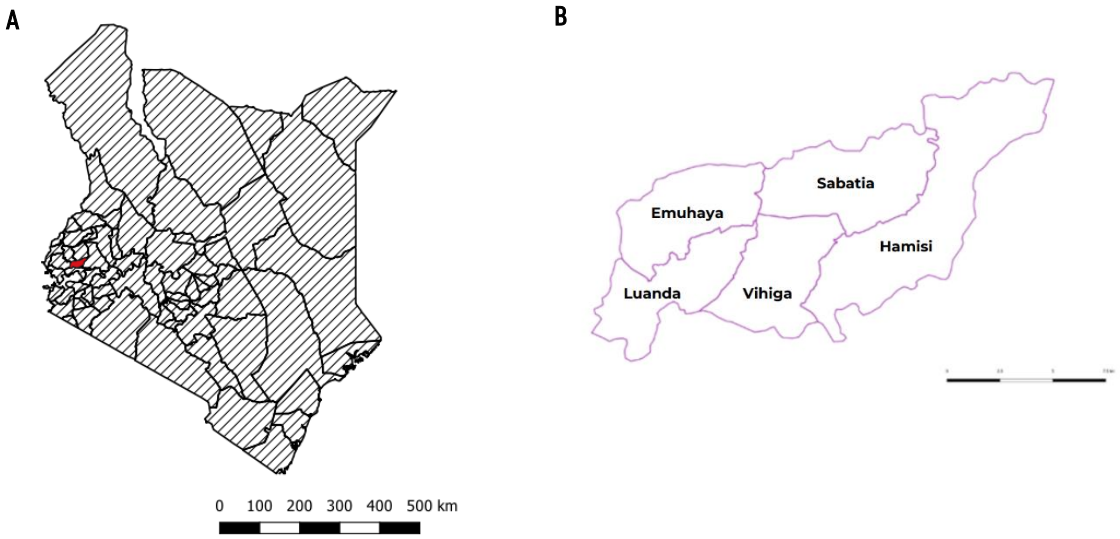


Figure 7: A. Vihiga County located in Western Kenya.; B. Five sub-counties in Vihiga (Luanda, Emuhaya, Sabatia, Vihiga and Hamisi).

3.1.1 Demographics

Vihiga County comprises 1.24% of Kenya's total population and has 590,013 inhabitants distributed among 143,365 households, each with an average size of 4.1 individuals. Due to its limited area of 563.8 km^2, Vihiga County stands out for having one of Kenya's highest population densities, with 1047 individuals per km^2 (KNBS, 2019). This has resulted in a pressure on land and other resources, leading to food insecurity and turning the county into a net food importer. Additionally, it has caused a high unemployment rate and continuous land disputes. The population is composed of 52% females and 48% males, indicating a slightly higher representation of women in the overall demographic composition. 85% of the population lives in rural areas (KNBS, 2019). In terms of economic conditions, approximately 39% of Vihiga County's population falls below the poverty line, which is less than $1.90 per day. This is slightly lower than the national average of 45%. Comparing this to the previous Vihga County Integrated Development Plan planning period, there has been a 2% decrease (County Government of Vihiga, 2013; 2023).

3.1.2 Climate

Vihiga County typically experiences an average temperature of approximately 23°C, fluctuating between a minimum of 14°C and a maximum of 32°C. The region is characterized by two distinct rainy seasons annually, with rainfall totals ranging between 1800mm and 2000mm, thereby enabling two separate planting seasons. The longer and wetter rainy period spans March, April, and May, while the shorter rainy season occurs in September, October, and November. Such climatic conditions are favourable for supporting a diverse range of species, a result of the combination of different habitat types. The diversity encompasses more than 310 tree species, 280 bird species, 220 butterfly species, and 100 moth species (Kindt et al., 2006). Vihiga County can be categorized into two distinct agroecological regions, specifically, the upper midlands and lower midlands (Jaetzold et al., 2010). The distinct climatic zones in Vihiga County influence both land-use practices and population distribution. The upper midland zone, covering Hamisi, Sabatia, and parts of the Vihiga sub-counties, is known for its fertile and well-drained soils. On the other hand, the lower midland zone, which includes the Emuhaya and Luanda sub-county, is distinguished by its red loamy sand soils, a result of the underlying sedimentary and basaltic rock formations (NARIGP et al., 2020).

3.1.3 Agriculture

Agriculture provides 80% of direct and indirect employment opportunities and contributes 34% of the Gross County Product (County Government of Vihiga, 2023). In terms of income, almost 40% of adult male-headed households derive their income from on-farm activities, along with about 13% of adult female-headed households and 3.6% of youth-headed households. Furthermore, about 76% of households have only one source of income, 18% have two sources, and 5.6% have three (ASDSP, 2014).

In Vihiga County, the average size of farms in the county is 0.4 hectares for small-scale farms and 3 hectares for large-scale farms. Regarding land use, 98.7% of the arable land is dedicated to mostly subsistence farming, while 1.3% is used for housing. The primary types of land use in the area are livestock rearing, crop farming, tree planting, fish farming, and residential settlements. The total arable land in Vihiga County is 404.8 km^2 which is 76% of the total area coverage. The county's high population density has resulted in the subdivision of land into parcels that are too small to be economically viable (County Government of Vihiga, 2018). The limited land resource has constrained the county's efforts to enhance the standard of living, particularly in the rural areas that remain undeveloped. This is due to the fact that agriculture, which is the primary economic production system, has a low yield as a result of both the limited land size and the declining soil fertility (Kihima, 2015).

Land in Vihiga County is largely privately owned by individuals and by the government. The proportion of parcels with title deeds stands at about 28%, with low ownership of title deeds by women and youths due to cultural barriers (County Government of Vihiga, 2018).

The subsistence crops are maize *(Zea mays L.)* and bean *(Phaseolus vulgaris L.)*, while tea (*Camellia sinensis L.)* and coffee (*Coffea sp. L*.) are the main cash crops. Moreover, farmers cultivate other crops such as sorghum *(Sorghum bicolor (L.) Moench),* millet *(Eleusine coracana (L.) Gaertn),* cassava *(Manihot esculenta Crantz),* sweet potatoes *(Ipomoea batatas (L.) Lam).,* and bananas *(Musa sp.).* Zebu cattle, dairy cattle and chicken are the main types of livestock kept by the farmers (County Government of Vihiga, 2018). Between 2018 and 2022, the agriculture sector aimed to boost crop production. During this period, maize productivity increased from 8 to 15 bags per acre, surpassing the target of 14 bags per acre. This success was primarily attributed to the increased adoption of organic fertilizers, certified seeds, and agrochemicals to combat army worms. Additionally, enhanced educational programs and extension services for farmers played a crucial role. The livestock sub-sector aimed to increase milk productivity from 1.5 litres per cow to 6 litres. By the end of the period, average productivity reached 3.5 litres per cow. Similarly, poultry farming saw significant growth, with the percentage of households raising improved poultry breeds rising from 12% in 2017 to 30% in 2022. Beekeeping, which includes honey production, has increased from 5% to 15%. (County Government of Vihiga, 2023). Together with guinea fowls, beekeeping receives a greater interest in the County (County Government of Vihiga, 2018). In terms of soil fertility, animal manure is the principal fertilizer used, but its availability and quality often fall short of the needs for maintaining soil health. The use of inorganic fertilizers is limited due to financial constraints faced by smallholder farmers (Waithaka et al., 2007).

Farmers in Vihiga County face numerous challenges that hinder their agricultural activities, ultimately impacting their livelihoods and the overall food security of the region. One of the most pressing issues is the limited access to credit and essential agricultural inputs. Without adequate financial resources and quality inputs, farmers find it challenging to adopt modern farming techniques and secure high-quality materials for their crops and livestock. Furthermore, post-harvest losses remain a significant concern for these farmers. Inadequate storage facilities and a lack of proper infrastructure contribute to substantial losses of agricultural produce. These losses not only reduce the income of farmers but also theaten the food security in the region. Pests and diseases represent another obstacle. Both crops and livestock in Vihiga County are susceptible to a range of pests and diseases, which significantly diminish yields and income for local farmers. The constant battle against agricultural threats requires consistent efforts and resources (Fred J., 2016). The county's vulnerability to climate change results in unpredictable weather conditions, including prolonged dry spells and flooding. Such extremes disrupt

crop production and livestock rearing, make it increasingly challenging for farmers to plan and sustain their agricultural activities (NARIGP et al., 2020). Lastly, limited market access remains a pressing challenge, adversely impacting their ability to secure fair prices for their produce and ultimately reducing their income. This issue is further exacerbated by a combination of factors, including inadequate infrastructure and a scarcity of accessible market information (Mutui E. & Aluso L., 2023).

3.1.4 Nutrition

According to KDHS conducted in 2014 and 2022, there has been a notable shift in the nutritional status of children and women within Vihiga county. For children under five years of age, the prevalence of stunting decreased from 23.5% in 2014 to 16.6% in 2022. In contrast, the rates of wasting shifted marginally from 2.6% in 2014 to 2.4% in 2022. However, the percentage of underweight children increased from 5.9% in 2014 to 9.2% in 2022 (KDHS, 2014; 2022).

The surveys also highlighted changes in the BMI among women. The mean BMI for women increased from 23.4 kg/m^2 in 2014 to 25.2 kg/m^2 in 2022. This rise is reflected in the growing prevalence of overweight and obesity among women; those classified as overweight increased from 19.3% in 2014 to 26.5% in 2022, and obesity rates rose from 8.3% to 16.9% over the same period. These data were gathered among women aged 15-49 in 2014 and adjusted to 20-49 in 2022 to better reflect the adult population (KDHS, 2014; 2022).

In Vihiga, the 2022 KDHS offered comprehensive insights into women's dietary habits, highlighting the consumption of various food groups. A significant 96.4% of women consumed grains. Meanwhile, 31.9% included white or pale starchy roots, tubers, and plantains in their diet, and 39.8% ate beans, peas, and lentils. Nuts and seeds were consumed by 16% of women, while dairy products such as milk, cheese, yogurt, or others were part of the diet for 83.5%. Meat, fish, poultry, or organ meats were eaten by 42.4%, and eggs by 12.8%. Dark green leafy vegetables were a dietary staple for 72.8%, other vitamin A-rich fruits and vegetables for 28.4%, other vegetables for 78.3%, and other fruits were consumed by 53.3% of women. Vihiga is among the counties with the highest consumption of unhealthy food by women, at 54%. However, 67.9% of women in Vihiga meet the minimum dietary diversity for women (KDHS, 2022).

3.2 Study design

For this research, fourteen sub-locations were sampled in Vihiga county. Agroecological interventions were promoted in ten sublocations, while the other four sub-locations served as control group without these interventions.

The agroecological interventions promoted are part of the project "*Diverse seeds and planting materials supporting farm resilience, inclusive value chains and healthy diets in a sustainable Vihiga County food system*", conducted by the Alliance of Bioversity and CIAT and the ten intervention sub-locations were originally randomly sampled from the list of 140 sub-locations in Vihiga. In each of the ten sub-locations, the project participants registered as self-help groups and the ten groups together formed a Community-Based Organisation (CBO). As part of the project, the CBO was supported to establish a central community seedbank containing 50 varieties (from ten species) of traditional leafy vegetables, 70 varieties of beans, fifteen varieties sorghum and seven millet varieties. The aim of the community seed bank is to transform it into a centre for the exchange of seeds, knowledge, and information. Furthermore, there are ten relay community seedbanks (one in each of the ten intervention sub-locations) spread across Vihiga County, each serving its community and contributing to the overall success of the project. Additionally, different agroecological practices were implemented in the communities, for instance, intercropping and composting.

The intervention sample was randomly selected from lists of group members who participated in the project, whereas the control group sample was randomly selected from the villages. Randomisation of both groups was done by using the RAND MS excel function. The farmer database was provided by the Alliance of Bioversity International and CIAT. The sample comprised households that included at least one woman within the age range of 15 to 49 years, while households lacking a woman within this age group were excluded from the sample.

3.3 Data collection

The data collection was conducted in September 2023. A total of 240 households (120 from the intervention group and 120 from the control group) were interviewed using two distinct qualitative surveys, the TAPE survey for assessing agroecology and an open 24-hour recall for assessing MDD-W (**Appendix E**). The data was collected by using electronic survey forms using KoBoToolBox, an online tool created especially for field data collection of the TAPE tool, and Formshare to collect the open 24-hour recall. Five enumerators were trained for four days, and the two tools were pre-tested. The TAPE tool was always implemented before the open 24-hour recall. It took approximately two hours to conduct the two surveys per farmer, instead of the suggested maximum three hours, one hour for step

R1 and two hours for step 2 of the TAPE tool, as stated by Mottet et al. (2020). This could be attributed to the experienced enumerators, adequate training, and the use of smartphones. This required further investigation.

The TAPE tool involves interviews with the farmers and observations of the enumerators to qualitatively evaluate the agroecological practices and performance. The TAPE tool also includes a list-based 24-hour recall; however, the aim was to achieve a more detailed understanding of the dietary diversity in Vihiga County, therefore a qualitative open 24-hour recall detailing all foods and ingredients was carried out. Respondents were asked to describe all the foods and beverages consumed the day previous to the interview (24-hour period). Additionally, they were asked to describe the ingredients in each food or dish, including their source, as well as the cooking method and the location where the food or beverage was prepared or consumed.

During the data collection period, there were some technical issues with the KoBoToolBox, which resulted in the loss of data. The informatics team of the FAO responsible for the app was contacted during this period and asked to resolve the errors. However, despite these efforts, some data was still missing. To address this, different enumerators returned to the households in question or contacted them to ask the lost questions again. Although, the data remained incomplete. Subsequently, the missing data was manually entered into the Excel document. Furthermore, once during the data collection, the KoBoToolBox was unable to save the data, necessitating the transfer of all XLM files to a computer. The responsible informatics specialist was then able to convert them into an Excel document.

3.4 Data analysis

3.4.1 Data cleaning and preparation

Data cleaning and preparation were conducted by using R software (R version 4.1.2). The data cleaning was conducted to remove duplicates and missing data. After the data cleaning, 239 households (120 from the intervention group and 119 from the control group) remained (**Table 2**). The TAPE data is linked by the same ID as the 24-hour recall. In the 24-hour recall, two households were duplicated and one did not have an ID linked with the TAPE tool. The data of the TAPE tool contained one duplication. After data collection, the FAO was contacted and the categorical variables that had numbers in the dataset were linked to their responses before being used for further analysis (**Appendix F**). Next, Generative Artificial Intelligence, was used as a supporting tool for data cleaning and analysis.

Table 2: Overview of the sub-locations of the households assessed.

Agroecological interventions		Control group	
Sub-locations	**Number of households**	**Sub-locations**	**Number of households**
LUANDA			
Emmaloba	11	Ebuhando	30
Mwitubwi	13		
EUMHAYA			
Ebunangwe	9		
Essunza	12		
Intumbu	15		
SABATIA			
Wanondi	12	Bugina	30
Mambai	12	Munogwa	30
VIHIGA			
Emanda	12		
Vigulu	12		
Masana	12		
HAMSI			
		Muhundu	30
	120		119

3.4.1.1 Step 0

The CAET typology, as proposed by Lucantoni et al. (2021), is a system for classifying farms based on their level of agroecological practices. According to this framework:

- Farms with a CAET score below 50% are labelled as 'non-agroecological'.
- Those with scores between 50% and 60% are described as in the early stages of transition, termed 'incipient transition'.
- Farms scoring between 60% and 70% are considered to be actively moving towards agroecology, hence classified as 'in transition to agroecology'.
- Farms with a score above 70% are classified 'agroecological'.

Due to the large number of farms with a CAET score under 50%, this category was further divided into three sub-categories: CAET scores of 40-50%, 30-40%, and those below 30%.

3.4.1.2 Step 1

Due to issues during the data collection, one household had an answer about animal welfare missing. The enumerator re-checked this and manually filled in the missing information in the Excel spreadsheet with the right value. The element 'Human and Social values' and the CAET total score needed to be recalculated manually.

3.4.1.3 Step 2

Economic dimension

There was no missing data for the economic indicators.

Environmental and health dimension

Some data were lost due to technical problems during the data collection, which prevented the analysis of integrated pest management strategies and pesticide use. A household claimed to have produced 10,000 kg of sugar cane, but this claim was disregarded as improbable and was removed from the dataset. Another household whose crop data were missing was also taken out of the analysis. Only 224 of the households reported owning animals. For the soil health there was no missing data. There were no missing data points when calculating the scores for pollinators, beekeeping, and natural vegetation.

Social dimension

There were also five households without a woman according to the data collection, but this was considered incorrect as the households were only selected when a woman was present to answering the MDD-W questionnaire. For this dimension there was missing data that was filled in by hand in the Excel document after the data collection.

Nutrition dimension

For the listed-based and open recall 24-hour recall there was no missing data. The FAO guidelines for the MDD-W were used to divide the food ingredients for the open 24-hour recall by food group (FAO, 2023) (**Appendix G**).

Governance dimension

In this dimension there was data missing but could be fixed by filling in the data by hand. When there was no man in the household, there were excluded from the dataset to calculate the secure land tenure for men.

3.4.2 Data analysis

For the data analysis, the TAPE guidelines were followed (FAO, 2019), with the exception of the social dimension, where the questions of the survey conducted in 2023 were modified with the questions of the guidelines of 2019. As a result, the FAO was contacted, and they provided the appropriate guidelines for performing the data analysis (**Appendix H**). Findings were considered significant when the p-values of the output were lower than or equal to 0.05. Furthermore, the intervention group is referred to as the agroecological zone, while the control group is known as the non-agroecological zone.

3.4.2.1 Step 0

The average composition was calculated for each CAET category, as well as the percentage of those employed by CAET. To calculate the total hectares of the households, the available common pasture is also included, which differs from the TAPE guidelines, which exclude them (FAO, 2019).

3.4.2.2 Step 1

The observation percentages are calculated for each CAET category. Further, a descriptive statistical analysis is performed on the CAET elements for the total population, agroecological zone, and non-agroecological zone. More specifically, the average, median, minimum, maximum, and standard deviation are calculated. The means for the elements that satisfied the two assumptions of normality distributed and homogeneity of the variances of the agroecological and non-agroecological zones were also compared using an unpaired t-test. Welch's t-test was used if the assumption of homogeneity of variances was not met, and a Mann Whitney U test was used if the assumption of normally distributed data was not met. Furthermore, the means of the CAET elements of the various categories satisfied the two assumptions of homogeneity of variance and normally distributed, ANOVA tests were used to compare them; Welch's ANOVA tests were employed for unequal variances. For the elements that were not normally distributed but had homogeneous variances, the Kruskal-Wallis test was applied. The Spearman correlation coefficient was used to calculate the correlations between the CAET elements.

3.4.2.3 Step 2

Economic dimension

The median was chosen to analyse data across all indicators due to the presence of outliers. For economic indicators such as gross value of production (GVP), value added (VA), and net income, FAO guidelines were followed. These measures are calculated per hectare of farming and per person working on the farm. crop production expenditures were aggregated from seed, fertilization, machinery, and pesticide costs per hectare for each household. For animal-related expenses, costs for feed, veterinary services, and livestock were totalled for each livestock unit. All calculations are done in Kenyan Shilling (KES). To calculate the indicator for the percentage of people earning less than $1.90 per day, the exchange rate from the first of September 2023 was used, where $1 equals 145.5 KES.

The methodology for assessing market orientation and revenue evolution perceptions followed the approach used by the FAO in the "Report on the Use of the Tool for Agroecology Performance Evaluation (TAPE) in Lesotho in the Context of the Restoration of Landscape and Livelihoods Project" (Lucantoni et al., 2022) (**Appendix I**).

Spearman's correlation was employed to explore the relationships between this indicator and the CAET elements. For the percentage of people earning less than $1.90 per day, the point-biserial correlation method was applied with 1 equal to yes and 0 to no.

Environmental and health dimension

The TAPE tool guideline was followed in calculating the mean soil health index for each CAET category. Using the TAPE tool guideline, the Gini-Simpson index was computed for pollinators, beekeeping, crops, animals, and natural vegetation. Since the data were not normally distributed, a Spearman correlation was used to determine the correlation between the indicators and the ten elements.

Social Dimension

Since the FAO's TAPE (2019) guidelines could not be applied to the survey's questions (2023) for this section, the FAO has been contacted to help with the calculation of the Women's Empowerment in Agriculture Index (WEAI). In addition, the young female and the women were added up to determine the percentage of women employed. The WEAI were correlated with the CAET elements using a Pearson correlation, as the data was normally distributed. However, as the data of employed women was not normally distributed, a Spearman correlation was used to calculate the correlation between the percentage of women employed and the CAET elements. No data analysis has been conducted on youth employment and emigration indicators.

Nutrition dimension

The dietary diversity indicator is calculated by averaging the MDD-W for all the CAET categories and the two zones, using both the listed-based 24-hour recall of the TAPE tool and the open 24-hour recall. To analyse the differences in MDD-W medians between the CAET category, the Kruskal-Wallis test was used because the data was not normally distributed, although variances were homogeneous. For comparing the medians of MDD-W between two zones, the Mann-Whitney U test was employed, given that the data did not meet the assumption of normal distribution. This test helped determine if there were significant differences between the zone medians. Next, the average percentages of food sources for each category were calculated. The median of the food expenditure per person in the household was calculated for all categories and both zones. A Spearman correlation was employed to determine the relationship between the CAET elements and the dietary diversity indicator, as well as the food expenditure per person in the household.

Governance dimension

The FAO guidelines are used to calculate the land tenure indicator for both men and women. The correlation between the land tenure of men and women and the CAET elements is calculated using the Spearman correlation.

3.5 Ethical approach

For this research project, we obtained ethical clearances from Institutional Review Board of the Alliance of Biodiversity International and CIAT and National Commission for Science, Technology & Innovation of Kenya (License No: NACOSTI/P/23/28607). Written consent was obtained from each participant before implementing the questionnaire. As a token of appreciation during house visits, a small compensation of sugar packets and tea leaves were provided.

4. Results

4.1 Step 0: Description of system and context

4.1.1 Gender and age composition

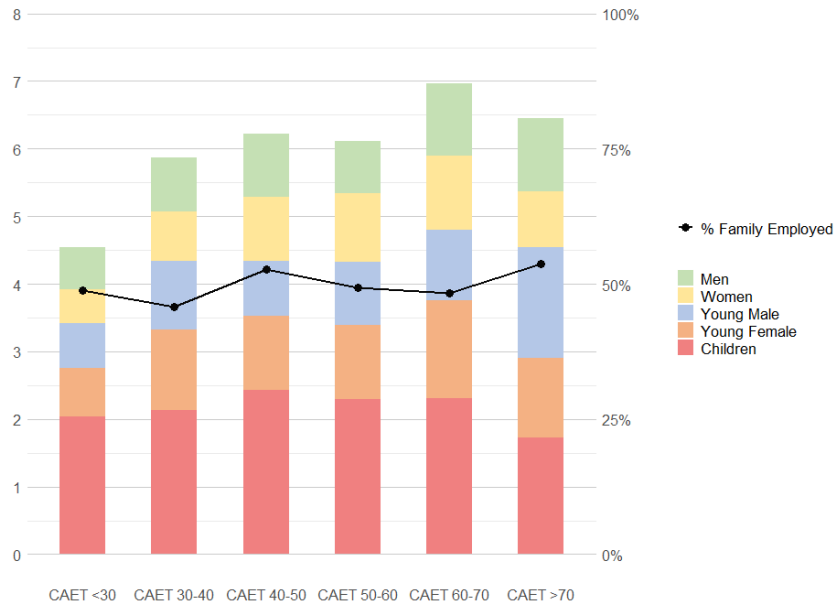


***Figure 8**: Gender and age composition per Characterization of the Agroecological Transition (CAET) categories.*

The smallest household size is found in the CAET <30 category, where young female members are closely followed by children as the primary contributors. The CAET 60-70 category contains the most members, followed by the CAET >70 group. The category CAET 30-40 has the lowest percentage of people employed in agriculture, while the category CAET >70 has the highest percentage, followed by CAET 40-50. In category CAET >70, there is a noticeable number of young male members, contrasted by a reduction in the children's share (**Figure 8**). For the entire sample population, the average household size is 6.1, with 33% women, 31% men and 36% children (For additional details, see **Appendix J**).

4.1.2 Size of productive systems and use of land

The average land area allocated for diverse uses such as farming, natural vegetation, pasture, and common pastures available across various CAET categories. Farming is the main use of the land of the households for all the CAET categories. There is an increase in land area from the CAET <30 to the CAET 60-70 group, with a noticeable peak in the latter, primarily due to a substantial portion of land dedicated to farming purposes. Interestingly, in the CAET >70 category, there is a decrease in the total land area, with farming and pasture purposes remaining prominent (**Figure 9**; For additional details, see **Appendix L**).

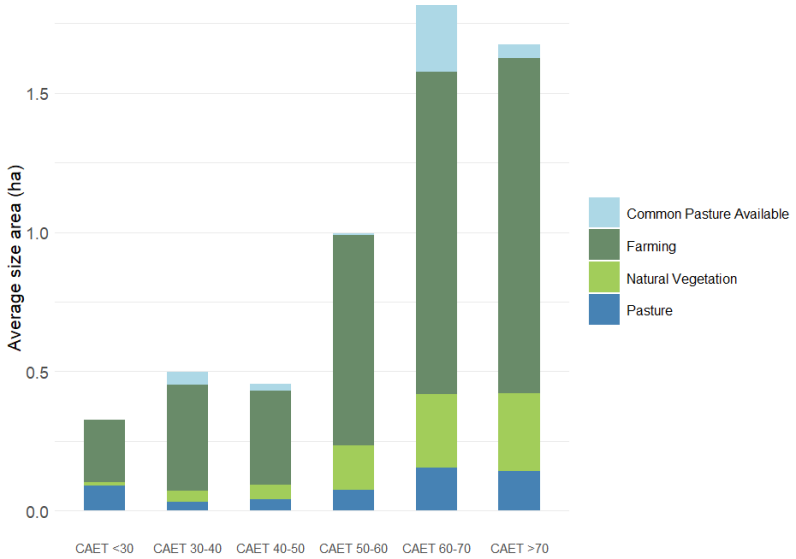


Figure 9: Average surface of land for farming, pasture, and natural vegetation per Characterization of the Agroecological Transition (CAET) categories.

4.2 Step 1: CAET in Vihiga County

4.2.1 Observations of the CAET categories

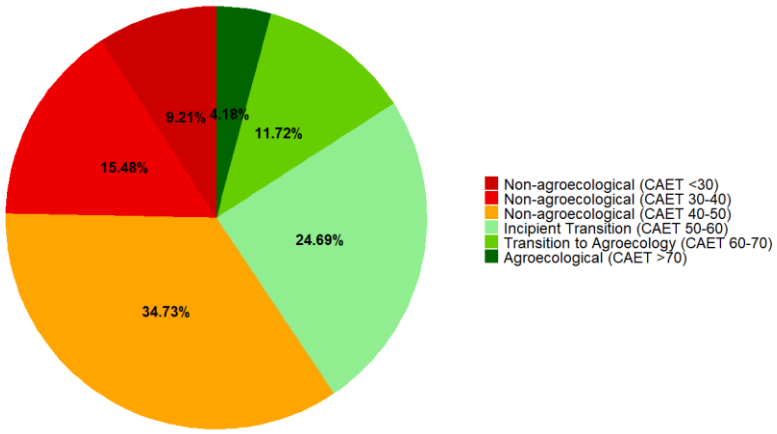


Figure 10: Percentages of the observations of each Characterization of the Agroecological Transition (CAET) category.

Figure 10 illustrates the distribution of observations across various stages of agroecological transition within the sample population. The majority of observations, representing 59.42%, fall into the non-agroecological categories (CAET <30; 30-40; 40-50). These classifications implies that many practices are not yet agroecologically oriented. The 'incipient transition' category contains 24.69% of the observations, indicating a movement toward the initial stages of implementing agroecological practices. A further 11.72% of observations are in the 'transition to agroecology' stage (CAET 60-70), signifying practices that are progressing towards agroecological methods. However, only 4.18% of the

observations are categorized as 'agroecological' (CAET > 70), reflecting a small subset of practices that have fully integrated agroecological principles.

4.2.2 CAET for the total sample of surveyed households in Vihiga County

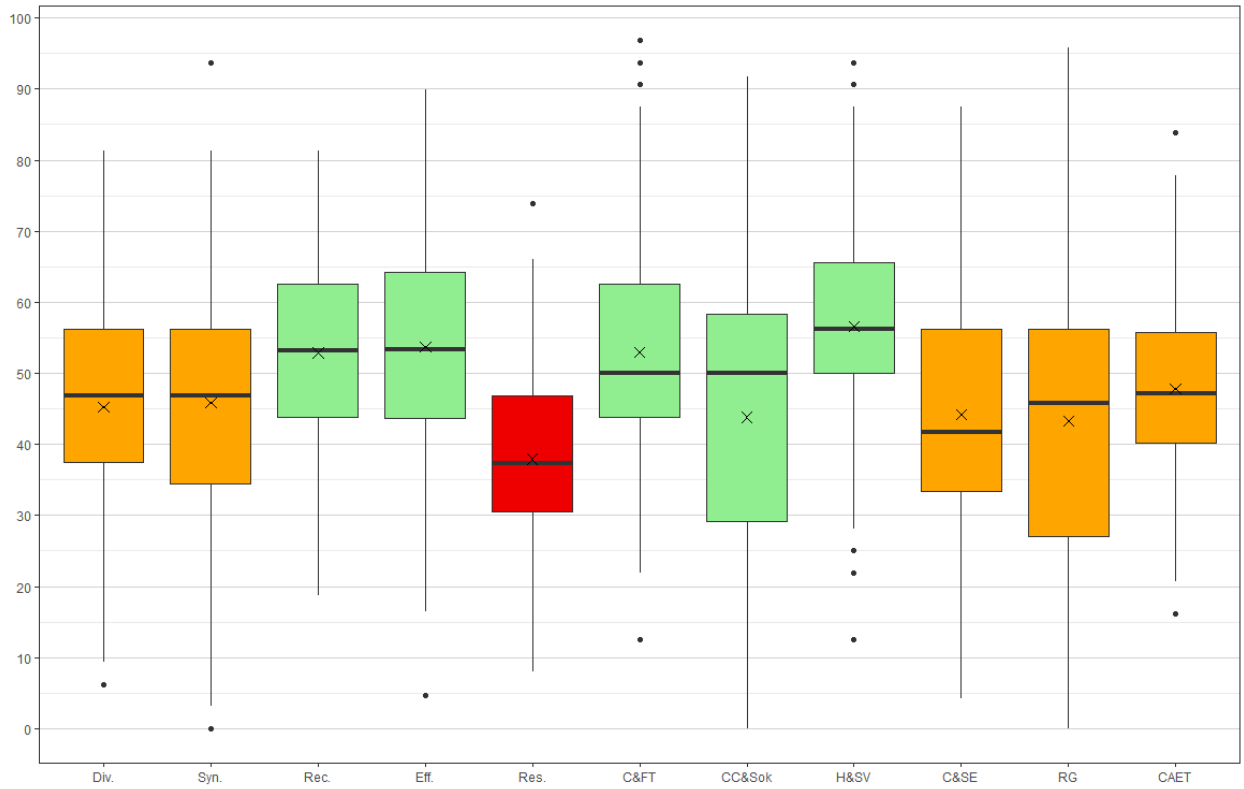


Figure 11: Descriptive statistical analysis of Characterization of the Agroecological Transition (CAET) elements of total sample of the population (Div.: diversity, Syn.: synergies, Rec.: recycling, Eff.: efficiency, Res.: resilience, C&FT: culture and food traditions, CC&Sok: co-creation and sharing of knowledge, H&SV: human and social values, C&SE: circular and solidarity economy, RG: responsible governance).

Figure 11 presents the quantitative results of the evaluated ten elements of CAET. The results are displayed as boxplots to visually represent the distribution and variability of CAET scores across the study. The element 'Diversity' exhibited a mean score of 45.26%, indicating moderate performance. The distribution spanned from a minimum of 6.25% to a maximum of 81.25%, showing substantial variability in responses as reflected by a standard deviation of 14.63%. The element 'Synergies' closely followed, with a mean of 45.82% and an even broader range of scores, the lowest reaching 0% and highest with 93.75%. This suggests that while there are peaks of high synergy, there is also significant inconsistency across observations, supported by a standard deviation of 16.51%. Elements 'Efficiency' and 'Recycling' were observed to have higher average scores of 52.9% and 53.7%. Element 'Resilience' has the lowest mean score of 37.94%. The substantial spread in scores, from 8% to 73.87%, and a moderately high standard deviation of 11.98% suggest a critical review of this aspect is warranted. 'Culture & Food traditions' scored better with an average of 52.92%. In contrast, 'Co-creation & Sharing of knowledge' was identified as a potential area for development with a lower mean score of 43.83%.

A wide range of responses was observed here, with scores ranging from 0% to 91.67%, signified by the highest standard deviation of 21.28% across all criteria. 'Human and Social values' were highlighted as the strongest element, with the highest mean score of 56.59%. Elements 'Circular and Solidarity economy' and 'Responsible governance' reported comparable mean scores of 44.16% and 43.25%, respectively, with 'Responsible governance' displaying the most considerable variation among respondents as indicated by the highest standard deviation of 21.49%. Lastly, the CAET total score that is calculated by the ten elements performed with a mean score of 47.8% (**Table 3**).

Table 3: Descriptive statistical analysis of Characterization of the Agroecological Transition (CAET) elements of total sample of the population (%).

	DIVERSITY	SYNERGIES	EFFICIENCY	RECYCLING	RESILIENCE	CULTURE & FOOD TRADITIONS	CO-CREATION & SHARING OF KNOWLEDGE	HUMAN & SOCIAL VALUES	CIRCULAR & SOLIDARITY ECONOMY	RESPONSIBLE GOVERNANCE	CAET
Mean	45.26	45.82	52.9	53.7	37.94	52.92	43.83	56.59	44.16	43.25	**47.8**
Median	46.88	46.88	53.13	53.37	37.31	50	50	56.25	41.67	45.83	**47.14**
Min	6.25	0	18.75	4.69	8	12.5	0	12.5	4.17	0	**16.18**
Max	81.25	93.75	81.25	89.88	73.87	96.88	91.67	93.75	87.5	95.83	**83.79**
σ	14.63	16.51	13.49	15.12	11.98	15.49	21.28	14.12	16.79	21.49	**12.38**

4.2.3 CAET for the agroecological zone and non-agroecological zone in of surveyed households in Vihiga County

Table 4: Descriptive statistical analysis of Characterization of the Agroecological Transition (CAET) elements of the agroecological zone (%).

	DIVERSITY	SYNERGIES	EFFICIENCY	RECYCLING	RESILIENCE	CULTURE & FOOD TRADITIONS	CO-CREATION & SHARING OF KNOWLEDGE	HUMAN & SOCIAL VALUES	CIRCULAR & SOLIDARITY ECONOMY	RESPONSIBLE GOVERNANCE	CAET
Mean	49.01	50.31	55.73	59.88	42.48	59.32	57.12	61.4	51.6	54.83	**54.5**
Median	50	50	56.25	59.13	42.5	56.25	58.33	62.5	54.17	54.17	**53.65**
Min	12.5	12.5	21.88	23.19	11.37	25	12.5	21.88	8.33	8.33	**23.41**
Max	75	93.75	81.25	89.88	73.87	96.88	91.67	93.75	87.5	95.83	**83.79**
σ	13.26	15.97	13.1	13.62	11.5	14.18	15.14	14.6	16.21	18.01	**11.07**

Table 5: Descriptive statistical analysis of Characterization of the Agroecological Transition (CAET) elements of the non- agroecological zone (%).

	DIVERSITY	SYNERGIES	EFFICIENCY	RECYCLING	RESILIENCE	CULTURE & FOOD TRADITIONS	CO-CREATION & SHARING OF KNOWLEDGE	HUMAN & SOCIAL VALUES	CIRCULAR & SOLIDARITY ECONOMY	RESPONSIBLE GOVERNANCE	CAET
Mean	41.47	41.28	50.05	47.47	33.36	46.46	30.43	51.74	36.66	31.58	**41.05**
Median	43.75	43.75	50	46.13	33.19	43.75	33.33	50	37.5	33.33	**41.35**
Min	6.25	0	18.75	4.69	8	12.5	0	12.5	4.17	0	**16.18**
Max	81.25	75	81.25	80.75	56.88	81.25	70.83	87.5	70.83	87.5	**67.97**
σ	15.02	15.86	13.33	14.01	10.68	14.05	17.92	11.81	13.8	18.18	**9.69**

From **Table 4**, it can be observed that in the agroecological zone the element of 'Resilience' has the lowest mean (42.48%) and median (42.5%) values in comparison to all other elements. Conversely, the element of 'Human and Social values' has the highest values with a mean of 61.4% and median of 62.5%. On the other hand, the non-agroecological zone has very low results for 'Resilience' (Mean: 33.36%; Median: 33.19%), 'Co-creation and Sharing of knowledge' (mean 30.43%; median 33.33%), 'Circular and Solidarity economy' (mean 36.66%; median 37.5), and 'Responsible governance' (mean 31.58%; median 33.33%) (**Table 5**). The agroecological zone has higher percentages for each CAET element. There is considerable variability in some elements within each zone, especially in the agroecological zone for 'Circular and Solidarity economy' (16.21%) and 'Responsible governance' (18.01%), and in the non-agroecological zone for 'Co-creation and Sharing of knowledge' (17.92%) and 'Responsible governance' (18.18%) (**Appendix L** & **Appendix M**).

4.2.4 Comparison of CAET in the agroecological zone and the non-agroecological zone

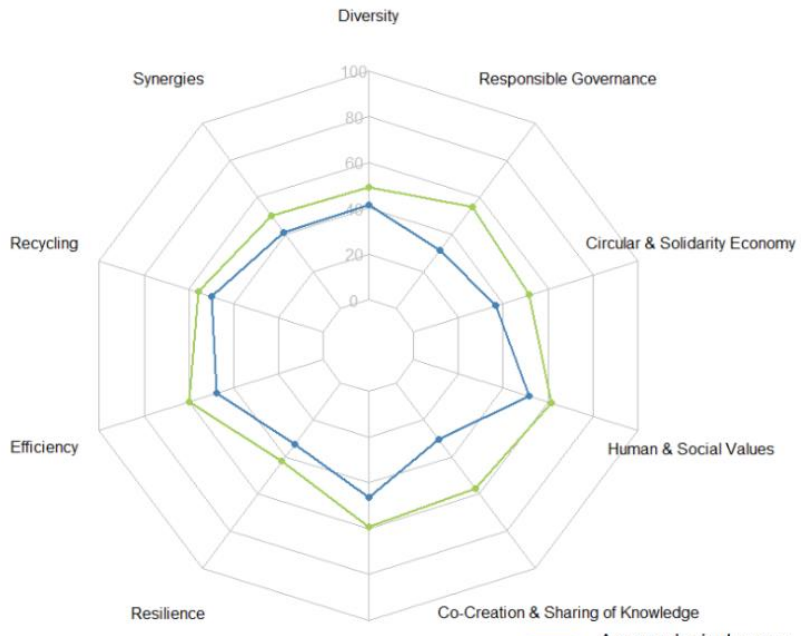


Figure 12: Characterization of the Agroecological Transition (CAET) elements results for the agroecological zone and the non-agroecological zone.

Table 6: Comparative analysis of Characterization of the Agroecological Transition (CAET) elements results for the agroecological zone and the non-agroecological zone (%).

Zones	# OF OBSERVATIONS	DIVERSITY	SYNERGIES	RECYCLING	EFFICIENCY	RESILIENCE	CULTURE & FOOD TRADITIONS	CO-CREATION & SHARING OF KNOWLEDGE	HUMAN & SOCIAL VALUES	CIRCULAR & SOLIDARITY ECONOMY	RESPONSIBLE GOVERNANCE	CAET
Agroecological Zones	120	49.01	50.31	55.73	59.88	42.48	59.32	57.12	61.40	51.60	54.83	**54.50**
Non-agroecological Zones	119	41.47	41.28	50.05	47.47	33.36	46.46	30.43	51.74	36.66	31.58	**41.05**

Figure 12 and **Table 6** illustrates the outcomes for ten elements across the agroecological zone and the non-agroecological zone. This analysis helps to identify the elements that are important in supporting the agroecological transition of households. Agroecological zones performed better for every CAET element. Elements with high score were 'Recycling' (55.73%), 'Efficiency' (59.88%), and 'Human and Social values' (61.40%) scored highly. In contrast, non-agroecological zones had lower scores for different elements, such as 'Resilience' (33.36%) and 'Circular and Solidarity economy' (36.66%).

The unpaired t-test was utilized for the elements 'Resilience', 'Culture and Food traditions' and CAET, to investigate the differences in means between the two zones. For the two elements and CAET, there are significant difference between the two zones (**Table 7**).

Table 7: T- test results between the agroecological zone and non-agroecological zone.

	t-value	p-value
Resilience	6.35	<0,001
Culture and Food traditions	7.05	<0,001
CAET	788.4	<0,001

The elements 'Diversity', 'Synergies', 'Efficiency', 'Co-creation and Sharing of knowledge', 'Human and Social values' were subjected to the Welch's t- test. For all these five elements there are significant mean differences between the zones (**Table 8**).

Table 8: Welch's t-test results between the agroecological zone and non-agroecological zone.

	t-value	p-value
Diversity	4.115	<0,001
Synergies	4.387	<0,001
Efficiency	6.944	<0,001
Co-creation and Sharing of knowledge	12.433	<0,001
Human and Social values	5.627	<0,001

The elements of 'Recycling', 'Responsible governance', and the 'Circular and Solidarity economy' underwent the Mann-Whitney U test tests. There are noticeable median differences between each of these elements, indicated by high W-values and low p-values. (**Table 9**).

Table 9: Mann-Whitney U test results between the agroecological zone and non-agroecological zone.

	W-value	p-value
Recycling	8949.5	<0,001
Circular and Solidarity economy	10795	<0,001
Responsible governance	11763	<0,001

Table 10: Distribution (%) of the zones agroecological and non-agroecological zone across the Characterization of the Agroecological Transition (CAET) categories.

	CAET <30	CAET 30-40	CAET 40--50	CAET 50-60	CAET 60-70	CAET >70
Agroecological zones	2.5	5.00	28.30	35.80	20.00	8.30
Non-agroecological zones	16	26.10	41.20	13.40	3.40	0.00

Table 10 shows the distribution of zones classified as agroecological and non-agroecological across different CAET Categories. Agroecological areas are more common in zones with higher CAET scores, especially in the categories CAET 50-60, 60-70, and >70; the category with the highest CAET score range is CAET 50-60, with 35.80% of the total. On the other hand, 16.00% of the CAET <30 category falls into the non-agroecological category. Non-agroecological zones that have a CAET score higher than 70% are absent.

4.2.5 Comparison of CAET of the Categories of agroecological transition

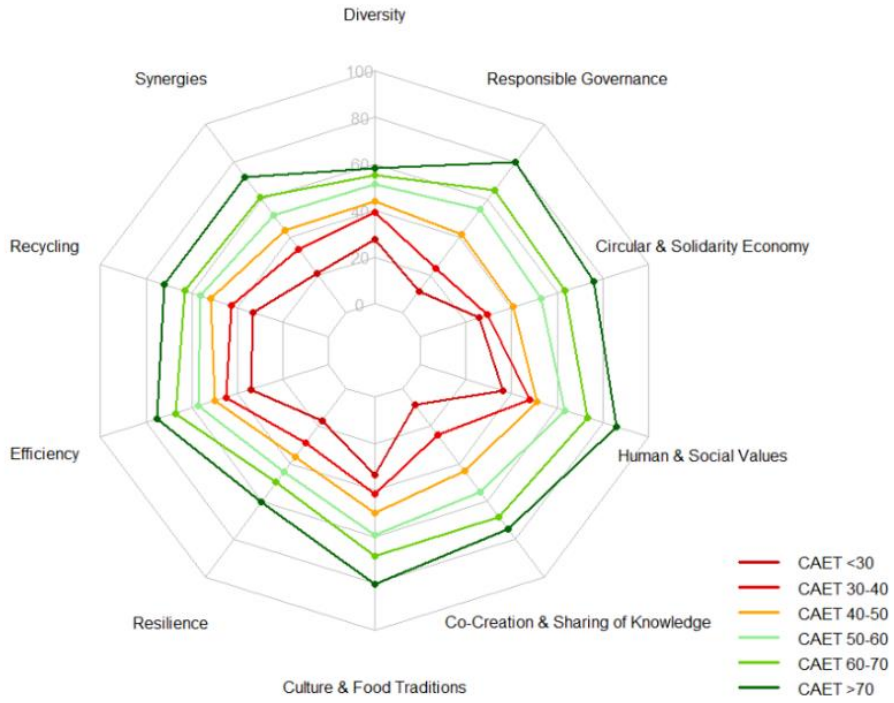


Figure 13: Characterization of the Agroecological Transition (CAET) elements results for each category of agroecological transition.

Table 11: Comparative analysis of Characterization of the Agroecological Transition (CAET) elements results for each category (%).

CAET category	# OF OBSERVATIONS	DIVERSITY	SYNERGIES	RECYCLING	EFFICIENCY	RESILIENCE	CULTURE & FOOD TRADITIONS	CO-CREATION & SHARING OF KNOWLEDGE	HUMAN & SOCIAL VALUES	CIRCULAR & SOLIDARITY ECONOMY	RESPONSIBLE GOVERNANCE	CAET
CAET <30	22	28.55	22.02	35.65	36.17	17.93	33.95	7.96	38.64	25.19	10.61	25.67
CAET 30-40	37	37.92	33.87	44.26	47.26	28.88	42.06	22.18	49.33	29.62	23.09	35.85
CAET 40-50	83	43.79	44.13	52.15	50.01	36.3	49.47	43.47	51.27	39.91	41.82	45.23
CAET 50-60	59	51.33	52.33	56.73	58.55	44.17	60.01	54.73	62.84	52.19	53.6	54.82
CAET 60-70	28	55.47	62.06	64.96	68.9	49.39	67.75	67.26	72.4	62.2	64.88	64.07
CAET >70	10	56.88	72.5	72.82	75.6	60.27	80	75.83	85.94	77.08	80	75.19

Figure 13 and **Table 11** illustrates the outcomes for ten elements across six CAET categories. This analysis assists in identifying the elements that play a significant role in enhancing the agroecological transition of households. The highest CAET category (>70) outperforms all other categories, with particularly high scores in 'Human and Social values' (85.94 %), 'Culture and Food traditions' (80%) and 'Responsible governance' (80%). In contrast, the lowest CAET category (<30) shows low scores, especially in 'Co-creation and Sharing of knowledge' (7.96%) and 'Responsible governance' (10.61%).

For the elements 'Resilience', 'Culture and food traditions', and total CAET, ANOVA tests were used to assess if there were mean differences among the categories. Significant differences were found among the categories for each of these elements, indicated by high F-values and low p-values. This suggests that the means of these variables differ significantly across the elements. (**Table 12**).

Table 12: ANOVA test results across all the Characterization of the Agroecological Transition (CAET) categories.

	F-value	p-value
Resilience	96.2	<0,001
Culture and Food traditions	50.55	<0,001
CAET	788.4	<0,001

The elements 'Diversity', 'Synergies', 'Efficiency', 'Co-creation and Sharing of knowledge', 'Human and Social values' were subjected to the Welch's ANOVA test. Significant differences are again evident across categories for these elements, as seen from the high F-values and low p-values. (**Table 13**).

Table 13: Welch's ANOVA test results across all the Characterization of the Agroecological Transition (CAET) categories.

	F-value	p-value
Diversity	19.621	<0,001
Synergies	57.195	<0,001
Efficiency	41.03	<0,001
Co-creation and Sharing of knowledge	184.65	<0,001
Human and Social values	98.807	<0,001

The elements of 'Recycling', 'Responsible governance', and the 'Circular and Solidarity economy' underwent the Kruskal-Wallis test. There are noticeable median differences between each of these elements, indicated by high χ2 and low p-values. (**Table 14**).

Table 14: Kruskal-Wallis test results across all the Characterization of the Agroecological Transition (CAET) categories.

	χ2	p-value
Recycling	95.668	<2e-16
Circular and Solidarity economy	140.82	<2e-16
Responsible governance	149.42	<2e-16

4.2.6 Correlations between the CAET elements

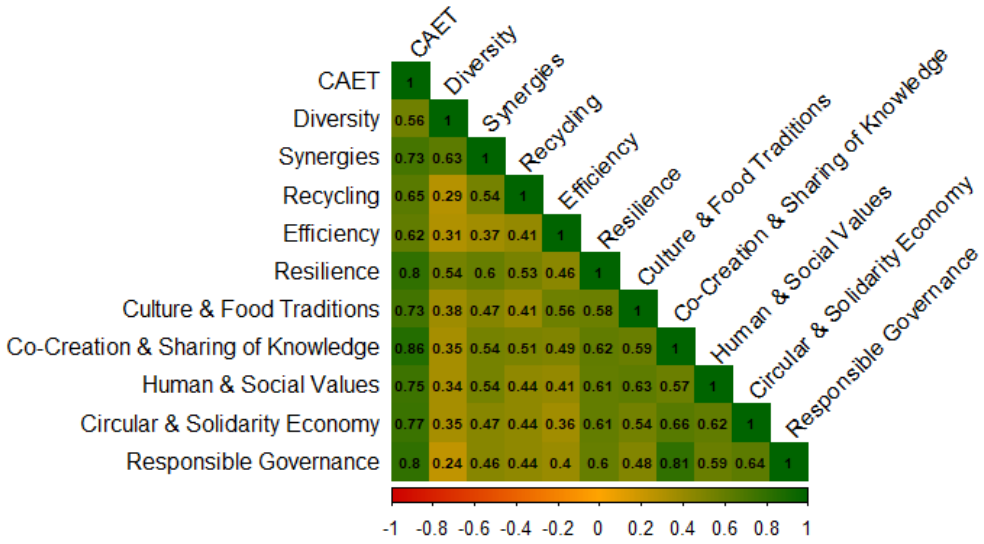


Figure 14: Correlations between the Characterization of the Agroecological Transition (CAET) elements.

Figure 14 displays the correlation coefficients among various elements of CAET, calculated using Spearman correlation analysis The strongest correlation is observed between 'Co-creation and Sharing knowledge' and CAET with a correlation coefficient of 0.86, indicating a positive relationship. Additionally, of all the elements, 'Diversity' has the lowest correlation coefficient with the CAET itself, at 0.56. Furthermore, 'Resilience' and 'Responsible governance' has also a strong positive correlation with CAET as well, with a correlation coefficient of 0.80. 'Diversity' shows moderate correlations with most other elements, with the highest correlation coefficient being with 'Synergies' (0.63) and the lowest with 'Responsible governance' (0.24).

4.3 Step 2: Multidimensional performance of agroecology

4.3.1 Economic dimension

The GVP per hectare (ha) shows a significant median increase from the lowest CAET < 30 (17,500 KES) category, peaking in the CAET 50-60 category (452,096 KES). The VA per ha, while starting negative in the CAET <30 category (-8,510 KES), shows a strong median increase and peaks in the CAET 50-60 range as well (318,000 KES) (**Figure 15**). Both GVP per Ha and VA per Ha have high standard deviations, especially in the CAET 30-40 (σ GVP per Ha = 32,947,816 KES; σ VA per Ha = 32,920,162 KES) and CAET 40-50 (σ GVP per Ha = 61,811,306 KES; σ Va per Ha = 61,814,030 KES), indicating considerable variability within these categories (**Appendix N**).

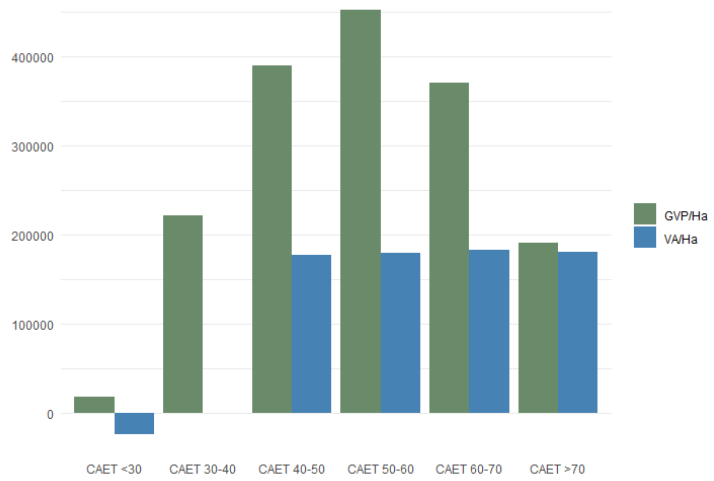


Figure 15: Households' gross value of the production (GVP) per hectare, value added (VA) per Characterization of the Agroecological Transition (CAET) categories.

GVP per person and VA per person both show significant increases from the CAET <30 category up through the CAET 30-40 category, with values peaking in the CAET 50-60 category. Notably, the CAET <30 category displays extremely low GVP values alongside negative VA. The standard deviations for both GVP and VA are particularly high in the middle categories (CAET 30-50), indicating substantial variability in economic outcomes for individuals within these categories (**Figure 16, Appendix O**). Furthermore, the percentage of people living on less than $1.90 per day remains high across all categories, peaking at 97% in the CAET 30-40 category. Despite a minor decline in these percentages as CAET scores increase.

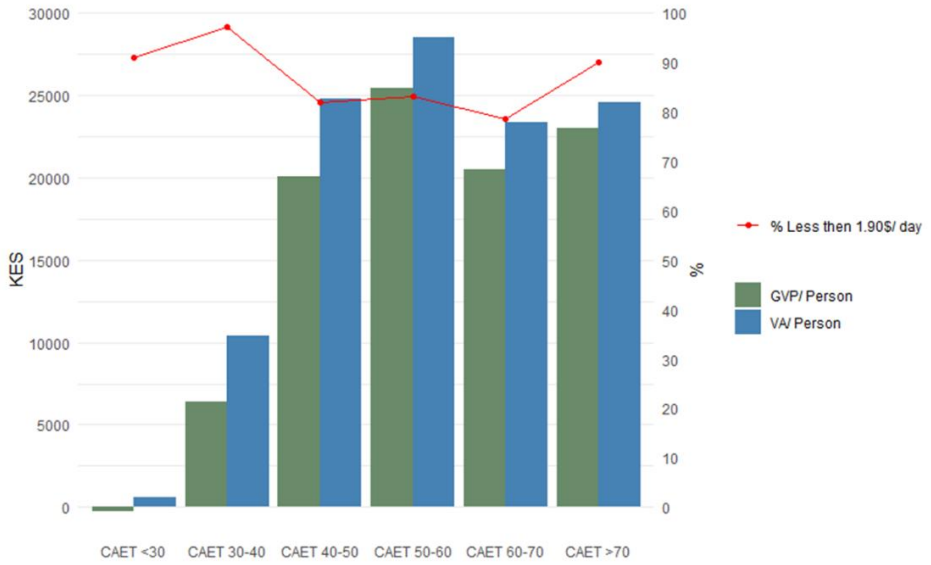


Figure 16: Households' gross value of the production (GVP) per person, value added (VA) per person and percentage of people earning less than $1.90 per day from the agropastoral activities per Characterization of the Agroecological Transition (CAET) categories.

Expenditures on crop production per hectare are highest in the CAET <30 category (31,500 KES). This trend generally declines as the CAET score increases, particularly for animal production expenditures. The expenditures on animal production per livestock unit (LSU) is less than on crop production for all categories. The highest animal expenditures are present in category CAET 30-40 (7,000 KES) and the lowest in category CAET >70 (500 KES) (**Figure 17**).

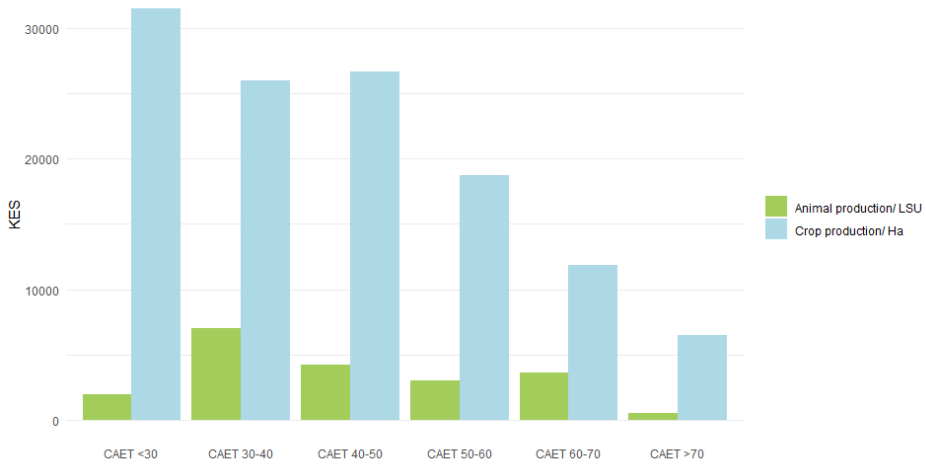


Figure 17: Expenditures for animal production per livestock unit (LSU) and Crop production per hectare (Ha) per Characterization of the Agroecological Transition (CAET) categories.

The CAET<30 category has a negative median net income per person (-838 KES). The next category, CAET 30-40, shows a significant improvement with a median net income of 6,371 KES. However, the standard deviation of net income per person highlights substantial variability within categories, particularly in the middle ranges (CAET 30-40 to CAET 50-60). This indicates high income variability within these categories. For example, the CAET 40-50 category features an exceptionally high standard deviation of income (3,509,067 KES). The perception of the evolution of revenues generally improves as the CAET score increases, reaching its peak (81%) in the CAET 40-50 group. Conversely, the market orientation score shows a clear rise, achieving its highest at 32% in the CAET 60-70 group (**Figure 18**).

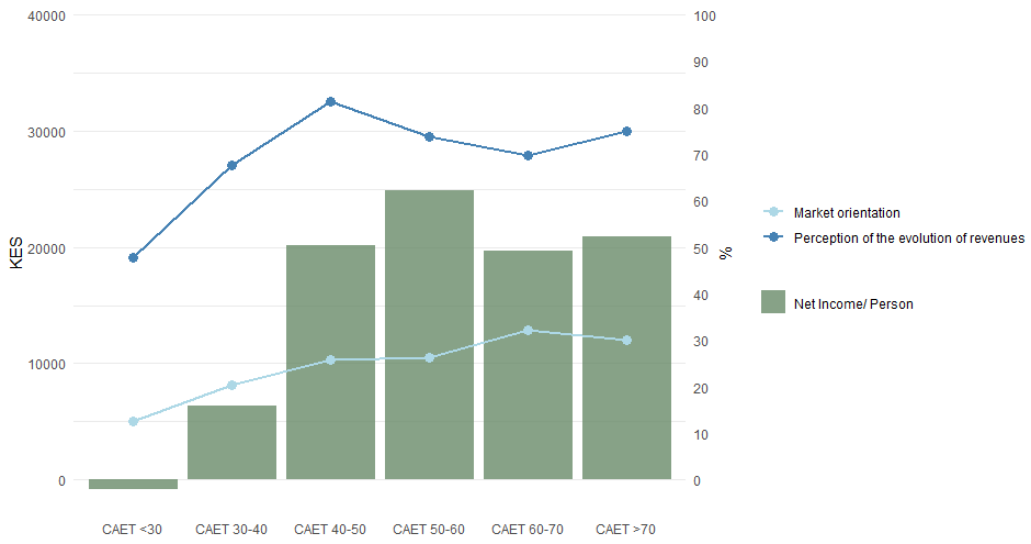


Figure 18: Results on net income per person of the households, percentage score of the market orientation of the agricultural production and the percentage score of the perception on the evolution of the income per Characterization of the Agroecological Transition.

Table 15: Statistical correlations between the economic indicators and the ten Characterization of the Agroecological Transition (CAET) elements.

Economic Indicators	CAET	Diversity	Synergies	Recycling	Efficiency	Resilience	Culture & food traditions	Co-creation & sharing of knowledge	Human & social values	Circular & solidarity economy	Responsible governance
Gross value of the production/ha	**0.2**	0.47	0.28	0.08	0.05	0.17	0.10	0.13	0.12	0.00	0.08
Value Added/Ha	**0.19**	0.45	0.25	0.07	0.07	0.15	0.11	0.13	0.10	-0.01	0.07
Expenditures crop production/Ha	**-0.29**	-0.14	-0.22	-0.09	-0.40	-0.17	-0.27	-0.23	-0.22	-0.20	-0.17
Expenditures animal production/LSU	**0.00**	0.31	0.10	-0.09	-0.04	0.02	-0.02	-0.08	-0.01	-0.08	-0.05
Gross value of the production/pers	**0.29**	0.53	0.32	0.10	0.10	0.22	0.21	0.21	0.18	0.11	0.15
Value added/pers	**0.25**	0.48	0.28	0.07	0.1	0.19	0.19	0.19	0.14	0.08	0.12
% people earning less than $1.90 /day	**-0.10**	-0.26	-0.23	-0.06	-0.02	-0.11	-0.05	-0.04	0.00	-0.01	0.01
Net income/pers	**0.33**	0.39	0.29	0.07	0.19	0.20	0.29	0.33	0.19	0.20	0.21
Perception of the evolution of revenues	**0.15**	0.17	0.10	0.07	0.13	0.07	0.16	0.20	0.05	0.01	0.14
Market orientation	**0.31**	0.45	0.39	0.14	0.07	0.25	0.17	0.26	0.17	0.24	0.22

Table 15 illustrates the statistical correlations between various economic indicators and both the level of CAET and the ten elements of agroecological transition. The GVP per ha exhibits moderate positive correlations with 'Diversity' (0.47) and 'Synergies' (0.28). Similarly, the VA per ha shows moderate positive correlations with 'Diversity' (0.45) and 'Synergies' (0.25). Conversely, expenditures on crop production per ha are moderate negatively correlated across all elements, most notably with 'Efficiency' (-0.40), suggesting that more efficient practices can significantly reduce crop production costs. Expenditures on animal production per LSU display weak to negligible correlations with most elements, though there is a moderate positive correlation with 'Diversity' (0.31). The GVP per person strongly correlates with 'Diversity' (0.53) and 'Synergies' (0.32). VA per person also shows strong positive correlations with 'Diversity' (0.48) and 'Synergies' (0.28), mirroring the trends observed per ha. The percentage of people earning less than $1.90 per day exhibits moderate negative correlations with 'Diversity' (-0.26) and 'Synergies' (-0.23). Net income per person shows moderate correlations with CAET (0.33), 'Diversity' (0.39), and 'Co-creation and Sharing of knowledge' (0.33), highlighting the economic benefits of comprehensive agroecological strategies. The perception of the evolution of revenues correlates moderately with 'Co-creation and Sharing of knowledge' (0.2) and 'Diversity' (0.17). Market orientation is moderately correlated with 'Diversity' (0.45) and 'Synergies' (0.39). The elements of 'Diversity' and 'Synergies' have the strongest relationships with the GVP, VA, net income, and market orientation.

4.3.2 Environmental and health dimension

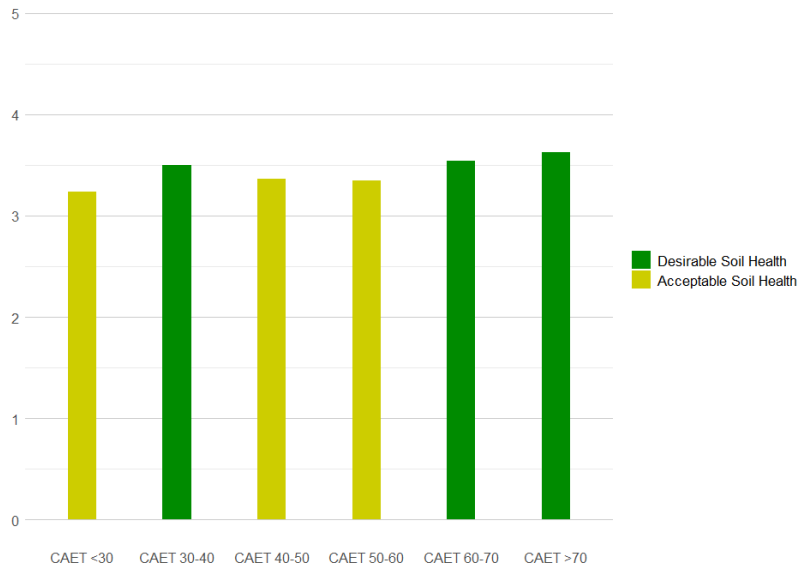


Figure 19: Average Soil Health index per Characterization of the Agroecological Transition (CAET) categories.

The average soil health index remains relatively constant across all categories of agroecological transition (CAET). The categories CAET 30-40 (3.5), CAET 60-70 (3.5), and CAET >70 (3.6) all have a desirable soil health, while the other categories demonstrate an acceptable soil health. There is no category that shows unsustainable soil health (**Figure 19**).

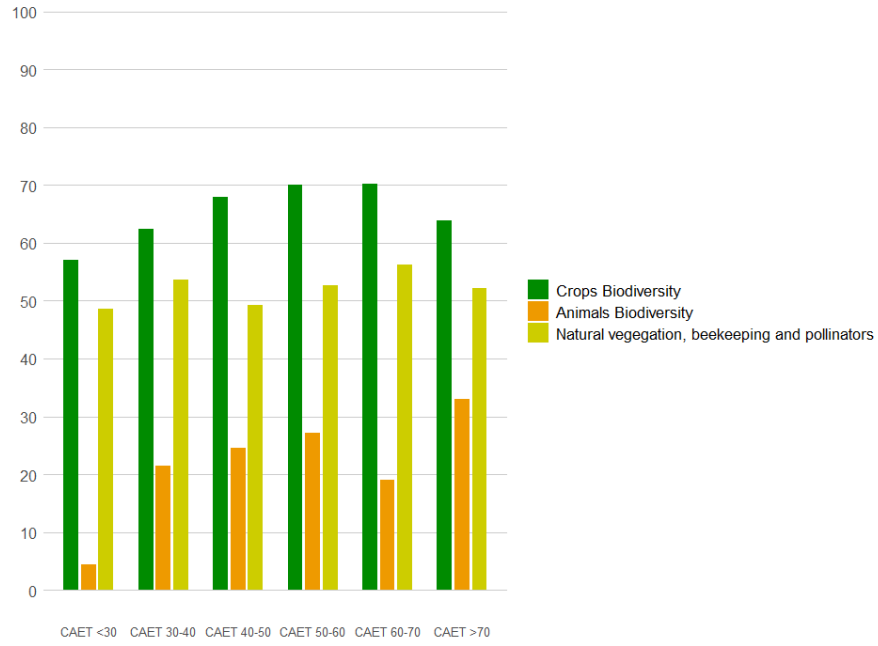


Figure 20: The average percentages of natural vegetation and pollinators, and crops and animals' biodiversity per Characterization of the Agroecological Transition (CAET) categories.

The average percentage of crop biodiversity for each agroecological transition, calculated by using the Gini-Simpson index, peaks in the CAET 60-70 category at 70.29%. There is an overall upward trend in crop biodiversity as the CAET categories progress, with the exception of a slightly decline in the highest category, CAET >70, which falls to 63.88%. Among the 224 households owning animals, the average animal biodiversity percentage, also determined by the Gini-Simpson index, shows more variation than the crops. There is an increase from the lowest category, CAET <30, at 4.41% to the highest, CAET >70, at 32.95%. The average percentage for natural vegetation, beekeeping, and pollinators remains relatively stable across the CAET categories, with minor fluctuations, particularly in the CAET 30-40 category (53.66%) and in CAET 60-70 (56.29%). Across all the agroecological transition categories, the average percentage of animal biodiversity is lower than that of crops biodiversity (**Figure 20**). The most common animals in all CAET categories are chickens, cows, and goats. Rabbits are found in all categories except CAET < 30. In terms of crop production, agroecological categories produce more bananas, fresh vegetables, and maize than non-agroecological categories. Cassava production is primarily seen in non-agroecological categories (**Appendix P** & **Appendix Q**).

Table 16: Statistical correlations between the environmental and health indicators and the ten Characterization of the Agroecological Transition (CAET) elements.

Environment and health indicators	CAET	Diversity	Synergies	Recycling	Efficiency	Resilience	Culture & food traditions	Co-creation & sharing of knowledge	Human & social values	Circular & solidarity economy	Responsible governance
Soil health	**0.10**	0.18	0.12	0.01	0.20	0.13	0.16	-0.02	0.11	-0.03	0.01
Natural vegetation, beekeeping and pollinators	**0.09**	-0.05	0.01	0.10	0.16	0.02	0.06	0.11	0.04	0.11	0.09
Crop Biodiversity	**0.18**	0.29	0.17	0.05	0.11	0.08	0.11	0.15	0.16	0.05	0.12
Animal Biodiversity	**0.05**	0.26	0.20	0.17	0.14	0.09	0.04	-0.08	-0.04	-0.04	-0.03

Statistical correlations between environmental and health indicators and the ten elements of agroecology transition, show different outcomes. Indicator 'Soil health' shows a positive correlation with different elements, notably with 'Efficiency' (0.20) and Culture and Food traditions (0.16), but still weak. 'Natural vegetation, beekeeping, and pollinators' present negligible results. 'Crop biodiversity' displayed strong positive correlations, particularly with 'Diversity' (0.29), 'Synergies' (0.17), 'Human and Social values' (0.16) and 'Co-creation and Sharing of knowledge' (0.15). Positive correlations have been found between 'Animal biodiversity' and 'Diversity' (0.26) and 'Synergies' (0.20). Further, 'Crop Biodiversity' has the highest correlation with the agroecological transition (CAET) (0.18) comparing to 'Soil health' (0.10), 'Natural vegetation, trees, and pollinators' (0.09) and Animal Biodiversity (0.05) (**Table 16**).

4.3.3 Social dimension

Table 17: Average score of the five indicators of Women's Empowerment in Agriculture Index (WEAI) per Characterization of the Agroecological Transition (CAET) category.

CAET category	Productive decision	Decision making	Leadership	Time use	Income use	WEAI
CAET <30	50.3	41.7	64.8	74.5	52.1	**56.7**
CAET 30-40	53.3	42.0	63.5	88.6	50.9	**59.6**
CAET 40-50	47.9	42.4	68.4	89.7	46.2	**58.9**
CAET 50-60	53.5	50.3	79.2	90.8	56.9	**66.1**
CAET 60-70	46.9	46.7	83.0	91.9	46.1	**62.9**
CAET >70	59.4	53.7	85.0	100.0	50.8	**69.8**

The detailed WEAI is presented in **Table 17** , which divides the different indicators over the different CAET categories. The lowest WEAI score across all categories is observed in the category CAET <30, with an overall WEAI of 56.7%. Nevertheless, there is an improvement in CAET 30-40 category, with a WEAI of 59.6%. The CAET 40-50 and 50-60 categories demonstrate further improvement, with a WEAI of 58.9% and 66.1%. The CAET 60-70 and CAET >70 categories achieve the highest scores. These categories score higher for the indicator's 'leadership' 85% and 'time use' 100% and have an overall WEAI of 69.8%. Across all categories, 'leadership' and 'time use' scores are the highest, while decision making is the lowest (**Figure 21; Table 17**).

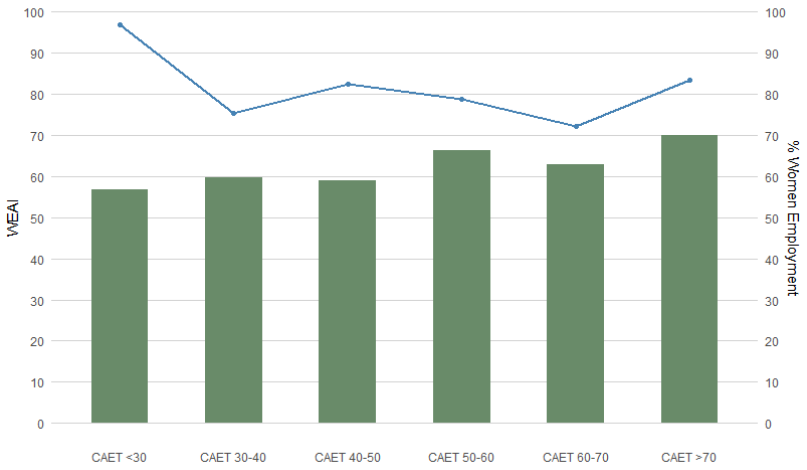


Figure 21: Women's Empowerment in Agriculture Index (WEAI) and percentage of women working on farm per Characterization of the Agroecological Transition (CAET) categories.

The category CAET <30 has the highest proportion of women employed in agriculture (96.8%). The lowest proportion of women employed is in CAET 60-70, with 72% of women (**Figure 21**).

Table 18: Statistical correlations between social indicators and the ten Characterization of the Agroecological Transition (CAET) elements.

Social indicators	**CAET**	Diversity	Synergies	Recycling	Efficiency	Resilience	Culture & food traditions	Co-creation & sharing of knowledge	Human & social values	Circular & solidarity economy	Responsible governance
WEAI	**0.26**	0.16	0.13	0.15	0.16	0.37	0.32	0.17	0.28	0.17	0.19
% women employement	**-0.11**	-0.23	-0.15	0.00	-0.08	-0.11	-0.08	-0.05	-0.12	-0.07	-0.08

Given that the WEAI is normally distributed, a Pearson correlation for all ten elements reveals a positive correlation. The elements with the highest correlations are 'Resilience' (0.37) and 'Culture and Food traditions' (0.32). A Spearman correlation was conducted on the percentage of women employed indicator due to its not normally distribution. Conversely, the percentage of women employed has negative correlations with every element, with the exception of 'Recycling', which has zero correlation. The element 'Diversity' has the strongest negative correlation (0.23) (**Table 18**).

4.3.4 Nutrition dimension

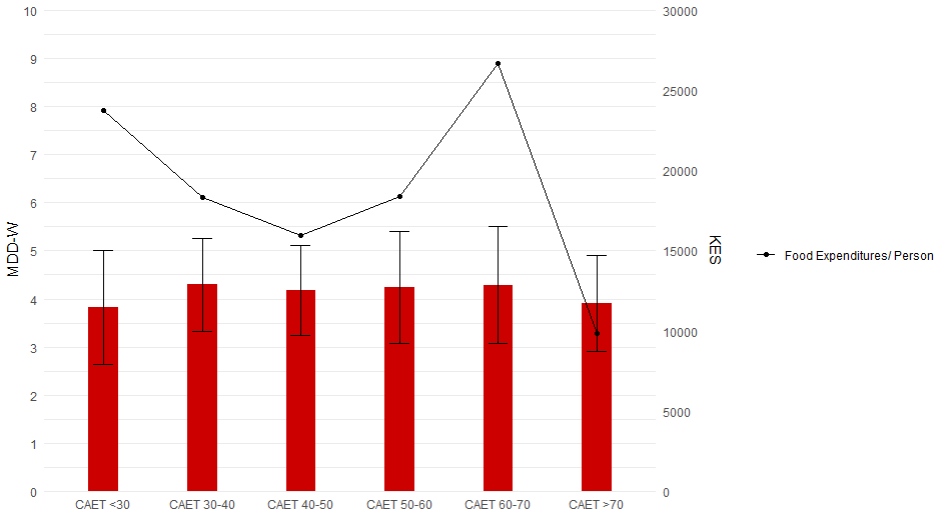


Figure 22: Minimum dietary diversity for women (MDD-W) and food expenditures per person per Characterization of the Agroecological Transition (CAET) categories.

Across all CAET categories, no category met the minimum of five groups for the open 24-hour recall. The average MDD-W is also consistent across all categories. CAET 30-40 has the highest MDD-W (4.35), while CAET <30 has the lowest (3.82). According to the Kruskal-Wallis test, there is no significant difference between the category's medians (p >0.05). Comparing the results to the listed-based 24-hour recall on the TAPE questionnaire reveals no significant differences, with the exception of category CAET 60-70 with MDD-W 5.36, which met the minimum requirement of five food groups. The highest category for food expenditures per person is CAET 60-70 (26,701 KES), while the lowest is CAET >70 (9,830 KES). Food expenditures per person decreased in the non-agroecological categories of CAET <30, CAET 30-40, and CAET 40-50 (**Figure 22**, **Appendix R**).

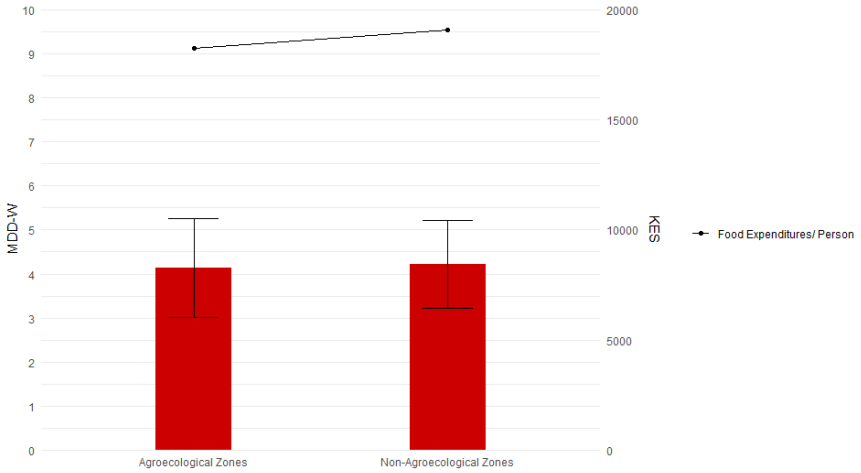


Figure 23: Minimum dietary diversity for women (MDD-W) and expenditures on food per person for the agroecological zones and non-agroecological.zones.

There is no significant difference in average MDD-W between agroecological (4.13) and non-agroecological zones (4.42). Both are lower than MDD-W's minimum five food groups (**Figure 23, Appendix S**). Based on the Mann-Whitney U test there is no significant difference between the MDD-W medians of the two zones ($p > 0.05$). The listed- based 24-hour recall is slightly higher that the open recall with for the agroecological zones 4.22 and the non-agroecological zones 4.81 as MDD-W score. Non-agroecological zones have a higher average food expenditure per person (19,077 KES) compared to agroecological zones (18,244 KES).

The consumption of food group 'grains, white roots, tubers and plantains' is notably high but shows a declining trend starting from the CAET 50-60 category. The food groups of 'nuts and seeds' are not consumed in the CAET 60-70 and CAET >70 categories. 'Milk and milk products' display an increasing trend in consumption across the various CAET categories, peaking in CAET >70. The category CAET >70 also has the lowest percentage of 'meat, poultry, and fish' consumption at 20%. 'Eggs' consumption is relatively low across all categories, with the highest levels observed at 14% in CAET 30-40 and lowest levels at CAET >70 (0%). Across all agroecological transition CAET categories, the food groups of 'grains, white roots, tubers and plantains', 'milk & milk products', 'dark green leafy vegetables', and 'other vitamin-A-rich fruits and vegetables' are consumed in high frequencies. In contrast, the consumption of 'nuts and seeds', 'eggs', and 'other vegetables' is notably lower (**Table 19**).

Table 19: Average % consumption of the ten food groups of the Minimum dietary diversity for women (MDD-W) per Characterization of the Agroecological Transition (CAET) category.

CAET category	Grains, white roots, tubers and plantains	Pulses	Nuts and seeds	Milk and milk Products	Meat, poultry and fish	Eggs	Dark green leafy vegetables	Other vitamin A-rich fruits and vegetables	Other vegetables	Other fruits
CAET <30	100	5	5	59	23	5	86	86	0	14
CAET 30-40	100	19	3	86	43	14	70	84	0	11
CAET 40-50	100	16	2	80	29	4	77	92	5	13
CAET 50-60	97	25	7	88	22	7	61	93	3	20
CAET 60-70	96	18	0	100	36	4	61	96	7	11
CAET >70	80	20	0	100	20	0	70	80	0	20

The consumption patterns across both agroecological and non-agroecological zones are very similar. However, a notable difference is observed in the consumption of dark leafy vegetables, where non-agroecological zones show higher consumption rates (80%) compared to agroecological zones (62%). In contrast, 'other vitamin-A-rich fruits and vegetables' are consumed more frequently in agroecological zones (95% versus 86%). Across the whole population sample in Vihiga, there is a notably low consumption of 'nuts and seeds', 'eggs', and 'other vegetables. Consumption of 'pulses', 'other fruits', and 'meat, poultry, and fish' also remains relatively low. Conversely, food groups such as

'grains, white roots, tubers and plantains', 'milk and milk products', 'dark green leafy vegetables', and 'other vitamin-A-rich fruits and vegetables' are consumed at higher rates (**Table 20**).

Table 20: Average consumption of the ten food groups of the Minimum dietary diversity for women (MDD-W) for the agroecological zones and non-agroecological zones.

Zones	Grains, white roots, tubers and plantains	Pulses	Nuts and seeds	Milk and milk products	Meat, poultry and fish	Eggs	Dark green leafy vegetables	Other vitamin A-rich fruits and vegetables	Other vegetables	Other fruits
Agroecological zones	96	18	6	85	29	4	62	95	5	14
Non-agroecological zones	100	18	1	83	29	8	80	86	2	15

Figure 24 illustrates the different food sources across different categories of agroecological transition (CAET). Market purchases are the primary source of food in all CAET categories, with percentages generally increasing as CAET levels rise. However, there is a noticeable decrease in market purchases in the CAET >70 category (64.7%). However, there is an upward trend in own production, peaking in the CAET >70 (28.3%). Conversely, neighbourhood purchases decrease with higher CAET categories, reaching their lowest in CAET 60-70 (5.6%). Gifts or aid contribute minimally across all CAET categories, highlighting that the majority of food sources are through market purchases and own production, rather than reliance on external assistance.

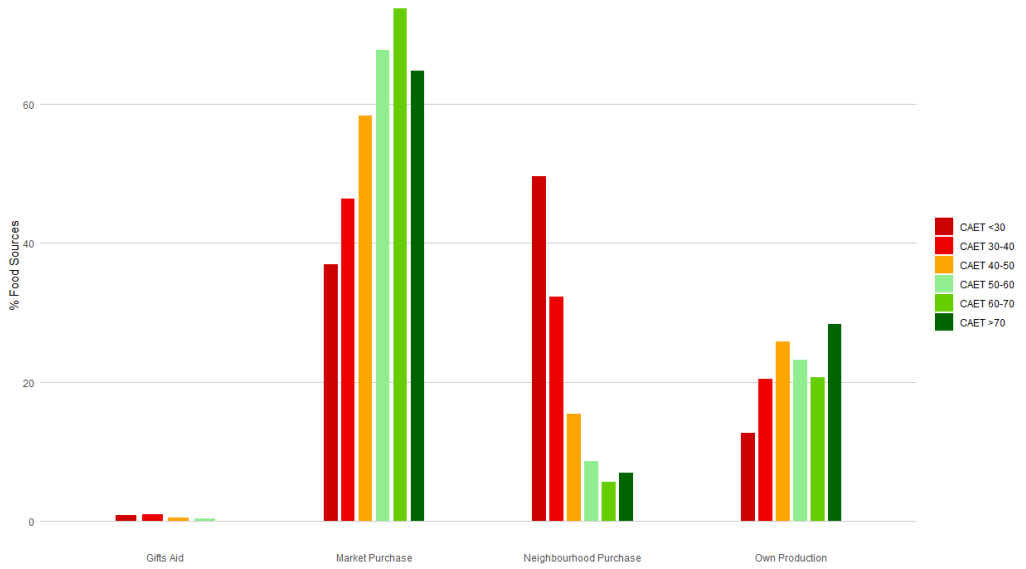


Figure 24: Percentages of food sources per Characterization of the Agroecological Transition (CAET) categories.

Table 21: Statistical correlations between the nutrition indicators and the ten Characterization of the Agroecological Transition (CAET) elements.

Nutrition indicators	CAET	Diversity	Synergies	Recycling	Efficiency	Resilience	Culture & food traditions	Co-creation & sharing of knowledge	Human & social values	Circular & solidarity economy	Responsible governance
Dietary diversity	**0.02**	0.15	0.03	0.05	-0.07	0.07	0.07	-0.02	0.03	-0.03	-0.05
Food Expenditures /person	**-0.14**	-0.03	-0.06	-0.03	-0.19	-0.05	-0.16	-0.19	-0.07	-0.15	-0.19

Statistical correlations indicate a weak relation between agroecological transition, MDD-W as an indicator and food expenditures per person. This correlation is weak across all agroecological transition categories (CAET). Among the CAET elements, 'Diversity' shows a modest positive correlation with dietary diversity (0.15), while 'Resilience' and 'Culture and Food traditions' has a positive weaker correlation (0.07). The element 'Efficiency' shows the most negative correlation (-0.07). The correlations between the food expenditures per person and the level of agroecological transition (CAET) are negative (-0.14). The elements with the strongest correlations are 'Efficiency', 'Co-creation and Sharing of knowledge', and 'Responsible governance', each with correlation coefficient of -0.19 (**Table 21**).

4.3.5 Governance dimension

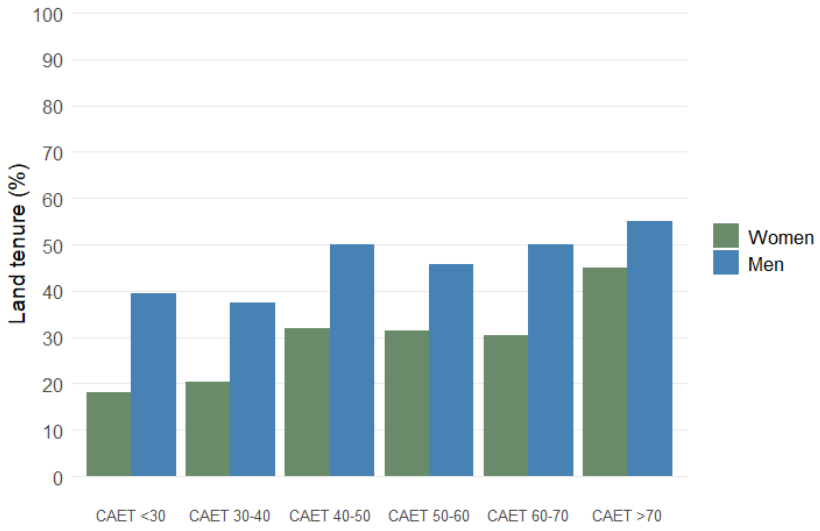


Figure 25: Average of secure land tenure for men and women per Characterization of the Agroecological Transition (CAET) (%).

Across all agroecological transition categories, men and women have low rates of secure land tenure. Women have the lowest land tenure rates in categories CAET < 30 (18.2%) and CAET 30-40 (20.3%). Men have better land tenure across all CAET categories, with the highest percentage of 55,0% found in CAET >70. Land tenure has increased slightly for both men and women (**Figure 25**; For additional details, **Appendix T**).

Table 22: Statistical correlations between the governance indicators and the ten Characterization of the Agroecological Transition (CAET) elements.

Governance indicators	CAET	Diversity	Synergies	Recycling	Efficiency	Resilience	Culture & food traditions	Co-creation & sharing of knowledge	Human & social values	Circular & solidarity economy	Responsible governance
Secure land tenure (men)	**0.10**	0.00	0.08	0.09	-0.02	0.17	0.15	0.14	0.02	0.09	0.09
Secure land tenure (women)	**0.18**	0.03	0.07	0.14	0.08	0.34	0.24	0.15	0.19	0.13	0.15

The Spearman correlation analysis between secure land tenure and the CAET elements attributes for both men and women revealed limited patterns. For men, the correlations generally appeared weaker compared to those for women, indicating a differential impact or association of land tenure security with these attributes based on gender. For men, the highest positive correlation was observed with 'Resilience' (0.17), followed by 'Culture and Food traditions' (0.15), and 'Co-creation and Sharing of knowledge' (0.14). In contrast, for women, the correlations were more pronounced across several elements. The strongest correlation was seen with 'Resilience' (0.34), followed by 'Culture and Food traditions' (0.24), and 'Human and Social values' (0.19). Overall, the correlations are low for both men and women (**Table 22**).

5. Discussion

5.1 The agroecological transition of Vihiga County

The application of the CAET framework in Vihiga shows only modest progress towards agroecology, with a total average CAET score of 47.80% and most (59.42%) farms, cannot be considered agroecological. All the assessed agroecological elements differ significantly across CAET categories, with the transition to agroecology and agroecological categories performing better than non-agroecological categories. This indicates the necessity for improvement in different areas of agroecology and could be addressed in the future with the proposed Vihiga agroecology policy (Chumba et al., 2024) (**Figure 11**, **Table 3**).

5.1.1 Areas of improvement in Vihiga's agroecological transition

Among the ten elements evaluated, 'Diversity', 'Synergies', 'Co-creation and Sharing knowledge', 'Circular and Solidarity economy', and 'Responsible governance' all scored below 50%, indicating areas of underdevelopment (**Table 3**). First, the 'Diversity' score of 45.26% shows a significant lack of variety in Vihiga, not only in agricultural aspects such as crops, livestock, and natural vegetation but also in income-generating activities. Remarkably, 76% of household incomes come from a single source, primarily agriculture, which also limits crop and livestock diversification (ASDSP, 2014; County Government of Vihiga, 2023). The low score of 43.83% for 'Co-creation and Sharing knowledge' indicates that farmers have limited knowledge of agroecological practices and principles, and there are few or no networks for the horizontal creation and transfer of knowledge and best practices (County Government of Vihiga, 2023). Next, the relatively low average score of 44.16% for 'Circular and Solidarity economy' demonstrates a need for adjustments on the supply side to facilitate these transitions. Additionally, the element 'Responsible governance' with a low average score of 43.25%, suggests that the existing governance framework might not have been robust enough to support agroecological practices or to promote diverse and sustainable agriculture prior to the policy's formulation (FAO, 2019). As a response, an agroecology policy has been incorporated into the Vihiga County Integrated Development Plan (2023–2027) as a key institutional component. This policy aims to offer evidence-based solutions to important problems within the larger agri-food system, including food poverty, resilience, agricultural diversification, population density, land carrying capacity, food safety, and soil health. For smallholder farmers, young people, and women in particular, this policy-making process brought to light several unique obstacles and opportunities (Chumba et al., 2024).

The element ‘Resilience’ scored the lowest among the ten elements, averaging 37.9%. Most producers experience unstable incomes and agricultural outputs, making them vulnerable to both natural and economic disruptions, with limited ability to recover (NARIGP et al., 2020; Kihima, 2015).

5.1.2 Achievements in Vihiga’s agroecological transition

Four elements, i.e., ‘Efficiency’, ‘Recycling’, ‘Culture and Food traditions’, ‘Human and Social values’, score above 50 percent, indicating a more integrated approach to these practices (**Table 3**). The element of ‘Efficiency’ scored slightly higher at 52.9%. This is primarily because most farms in the area produce their own inputs for agricultural production. Despite this, these farms face significant challenges in adopting modern farming techniques and securing high-quality materials for their crops and livestock. Consequently, overall productivity remains low. As a result, agricultural production alone typically fails to meet the household's needs (Fred J., 2016). Further, the element of ‘Recycling’ also has a slightly better score of 53.7 %, with farmers extensively reusing byproducts such as animal manure for field fertilization and recycling seeds from previous harvests (NARIGP et al., 2020). Additionally, crop rotation practices have been implemented to enhance soil health and reduce waste (County Government of Vihiga, 2018). Public institutions in Vihiga have embraced green initiatives like solar energy projects and solar water heating systems, despite the region's generally low use of renewable energy. Public education campaigns encourage biogas, bio-digesters, and clean energy sources to lessen reliance on wood fuels. Water-saving measures are still limited, highlighting an area for potential improvement (County Government of Vihiga, 2023). The ‘Human and Social values’ element achieved the highest score of 56.59%, showcasing substantial achievements but also indicating areas for improvement. Initiatives aimed at empowering women and youth through agribusiness included the formation of a County Youth Forum and the establishment of resource centres in five sub-counties. Vocational and technical training programs for youth were expanded. Health insurance support was maintained for expectant mothers, children, and the elderly, as well as assistance for people with disabilities by providing braille materials, wheelchairs, and scholarships for underprivileged students. Although not meeting the employment target of 5% for persons with disabilities, efforts included disability mainstreaming and policy development for vulnerable groups. Gender equality was supported by the Women Enterprise Fund, National Government Affirmative Action Fund, and increased participation of women in politics and government roles (County Government of Vihiga, 2023). The element of ‘Culture and Food traditions’ achieved a score of 52.92%. This can be linked to implementing a seed bank and farmer-to-farmer exchanges. The new agroecology policy of Vihiga aims to develop agroecology production models for farmers based on these successful cases to enhance traditional food and seed systems. It also involves engaging stakeholders to establish five community seed banks across Vihiga's sub-counties and revive traditional post-harvest food

festivals. It is recommended that past successes in farmer-to-farmer exchanges be highlighted to facilitate the sharing of effective adoption practices (Chumba et al., 2024).

5.2 The agroecological transition differences between the two zones

The CAET total score shows a difference of more than 10% between agroecological zones (54.50%) and non-agroecological zones (41.5%). This difference is particularly pronounced in 'Co-creation and Sharing of knowledge', 'Human and Social Values', 'Circular and Solidarity economy', and 'Responsible governance' (**Table 4**, **Table 5**).

In terms of 'Co-creation and Sharing of knowledge', establishing a community seed bank in agroecological zones has greatly facilitated the exchange of agricultural knowledge and expertise. This initiative not only improves local agricultural practices but also encourages the development of new seed conservation protocols, directly impacting knowledge sharing. The element 'Human and Social values' stands out as a strong performer in agroecological zones, achieving the highest score of 61.40% (**Table 4**). This success can be attributed to the project's focus on promoting seed sovereignty and providing access to diverse seed varieties, thereby empowering local communities, particularly vulnerable ones. This effort enhances social cohesion and ensures equal access to resources. The element 'Circular and Solidarity economy' also differs between the zones (**Table 4**, **Table 5**). The community-managed seed banks maintain locally adapted seeds at low costs and facilitate seed exchanges, which improves the local economy's circularity. Furthermore, implementing sustainable practices such as intercropping and composting reduces waste while increasing resource utilization, perfectly aligning with circular economy principles. The local community-based organizations' management of seed banks serves as an example of responsible governance. This arrangement fosters accountability and transparency by guaranteeing that community members maintain control over seed production and conservation. In addition, it encourages the creation of local laws and customs pertaining to the preservation of biodiversity, which are essential to sustainable growth (Vernooy et al., 2014).

Interestingly, the differences in the scores for 'Diversity' and 'Recycling' between agroecological and non-agroecological zones are relatively modest compared to other elements (**Table 4**, **Table 5**). The 'Recycling' element shows a 5% higher score in agroecological zones, a modest increase considering the implementation of practices like intercropping and composting. Similarly, the 'Diversity' score shows only a 7% higher score in agroecological zones compared to non-agroecological zones. While these differences are less pronounced, they still suggest that agroecological zones maintain a slightly

greater variety of plants and seeds, likely due to the presence of community seed banks and efforts to preserve local and traditional varieties.

A limitation is that various other organizations and NGOs also implement projects in this area, and we lack a comprehensive overview of these efforts.

5.3 Relations between the agroecological transition elements

The correlation coefficients depicted in the CAET analysis align well with the agroecological pathways and elements outlined by Wezel et al. (2020), emphasizing critical pathways for sustainable agriculture (**Figure 4**, **Figure 14**).

5.3.1 The importance of co-creation and governance in agroecological transition

The strong positive correlation (0.86) between 'Co-creation and Sharing of knowledge' and overall CAET performance supports the fundamental importance of education and stakeholder engagement in agroecological transitions. This element's high correlation indicates effective knowledge integration and stakeholder engagement, essential for fostering transformative changes within agroecological systems (Anderson et al., 2019). This is also confirmed by the increasing score for this element across all CAET categories (**Table 11**). Despite the documented importance of biodiversity in enhancing climate resilience and nutrition the 'Diversity' element shows a lower correlation (0.56) with CAET (Snapp et al., 2010). However, this suggests that while diversity is critical, its integration and measurement within broader agroecological transitions may require more robust strategies to capture its benefits fully. Additionally, the strong correlation of 'Responsible governance' (0.80) with CAET underscores its essential role, supporting the need for transparent and inclusive governance mechanisms. Effective governance facilitates the transition to agroecological practices by ensuring access to resources and promoting social justice, which is vital for sustainable and equitable agricultural development (FAO, 2012).

5.3.2 Strengthening the agroecological transition through resilience and circular economy

Nevertheless, the lack of recognition of resilience as a critical pathway in the literature by Wezel et al. (2020), there is a stronger correlation between 'Resilience' and CAET total score (0.80), than with 'Circular and Solidarity economy' (0.77) According to Wezel et al. (2020), these two elements are linked, and the results 0.61 support this. By improving economic stability and lowering reliance on outside markets and inputs, 'Circular and Solidarity economy' strategies like diversification, encouraging local food circuits, and lowering external inputs directly increase the resilience of agricultural and rural system (FAO, 2018a; Schipanski et al., 2016).

These correlations only indicate possible relationships between the elements and the total CAET agroecology score. Further research is needed to confirm these relationships.

5.4 The outcomes of the agroecological transition in Vihiga County

The agroecological outcomes in Vihiga County present a nuanced picture, with limited correlations between various dimensions and their indicators with the CAET elements or overall CAET score. However, the economic dimension shows the most significant relationships. Specifically, net income per person has the highest correlation with the total CAET score of all the performance indicators, at 0.33.

The analysis of agroecological outcomes in Vihiga County reveals economic benefits linked to 'Diversity'. The strongest positive correlation found between the GVP per person and the diversity of agroecological systems (0.53) suggests that diversity enhances economic returns. This aligns with the FAO's findings, highlighting that diverse agrifood systems can improve economic outcomes and access to affordable diets. Furthermore, the moderate positive correlation (0.45) between market orientation and biodiversity supports the FAO's perspective on diverse systems' adaptability to market demands, enhancing market positioning. An additional indication that agroecological practices with a higher score for 'Efficiency' can reduce costs is the significant negative correlation (-0.40) found between crop production expenses and efficiency. This is consistent with the FAO's emphasis on effective resource management as a critical element in reducing costs and enhancing food security within a variety of agrifood systems (FAO, 2019) (**Table 15**).

The correlations between the indicators, the CAET elements and overall CAET score were not significant for the environmental and health dimension. Wezel et al. 2020 recognized crop and animal biodiversity as a technique that contributes to better nutrition. Changes in how plant and animal diversity is used and managed can significantly impact how climate change-adaptive agricultural systems are as well as how nutritious diets they contribute to (Snapp et al., 2010). The findings are different from what Wezel et al. recognized. The element of 'Dversity' and crop biodiversity have the strongest correlation (0.29), which is similar for the and animal biodiversity and 'Diversity' with 0.26 (**Table 16**). Despite the small variations between the CAET categories, the Gini-Simpson index scores show that crops have higher biodiversity than animals across all CAET categories (**Figure 20**). Although Vihiga's soil is fertile and well-drained, soil erosion is a current issue (County Government of Vihiga, 2023; NARIGP et al., 2020). Throughout the CAET categories, the soil health varies very little and constantly stays within acceptable and desirable ranges (**Figure 19**).

In households, women play a significant role in a variety of areas, including food security, dietary diversity, and health. They support the preservation and sustainable use of biological diversity. As such, women play a critical role in reshaping food systems and creating resilient livelihoods (Smith & Haddad, 2015). With a correlation coefficient of 0.37, the social indicator WEAI result demonstrates a moderate relationship with the 'Resilience' element of CAET (**Table 18**).

However, the study shows that there are generally poor correlations between social indicators and the components of the CAET. Agroecological approaches give women a framework to become more autonomous by improving their negotiation and leadership abilities, gaining knowledge, taking action as a group, and having opportunities for commercialization (Kerr et al., 2019). The 'leadership' and 'time use' domains consistently achieve the highest scores across all CAET categories. This consistent performance underscores their critical importance in facilitating agroecological transitions. Moreover, there is an upward trend in which the WEAI scores gradually rise with advances in CAET categories (**Table 17**). This pattern emphasizes how advancing agroecological methods can help to improve women's empowerment.

In Vihiga County, both men and women have low rates of secure land tenure, with women's rates lower than men, this is confirmed by the results of this research (County Government of Vihiga, 2018) (**Figure 25**). Generally, there is a low correlation between secure land tenure and agroecological elements. The strongest correlation is between 'resilience' and secure land women (0.34) (**Table 22**). It implies that it could improve resilience by guaranteeing equal access to land, which can result in more equitable and sustainable outcomes in agroecological transitions (Wittvan man & James, 2022).

5.5 Agroecological transition and a healthy diet

5.5.1 Dietary patterns in Vihiga county

According to data from the KNBS, consumption levels of 'nuts and seeds' are low, a finding that is consistent with results from this study across all CAET categories and among the two zones (agroecological zones and non-agroecological zones). Similarly, the food groups 'eggs' and 'other vegetables' also recorded low consumption scores in all CAET categories and among the two zones. Notably, the consumption of 'other vegetables' is significantly lower than the general levels reported by the KNBS. In contrast, the food group 'other vitamin A-rich fruits' and 'vegetables' performed much better than the overall results from the KNBS (KNBS, 2022). This improvement can likely be attributed to the increase in Vitamin A supplementation rates, which surged from 54.2% in 2017 to over 80% in 2022 (County Government of Vihiga, 2023) (**Table 19**, **Table 20**).

5.5.2 Impact agroecological transition on dietary patterns

Numerous studies have confirmed improvements in FSN in households that use agroecological practices, indicating that agroecology positively affects nutritional outcomes, especially in low-income regions (Kerr et al., 2021). According to Wezel et al., the core principles of agroecology; inputs, fostering biodiversity, encouraging economic diversification, upholding social values and diets, promoting fairness, connectivity, and participation, all significantly enhance nutrition. This implies that when linked with the FAO's agroecology elements, specific elements; 'Efficiency', 'Diversity', 'Human and Social values', and a 'Circular and Solidarity economy' directly influence nutrition. However, the results do not support this assertion, as the dietary diversity indicator displays no significant correlation with the elements of the CAET or the overall CAET score. The strongest correlation found with dietary diversity is with the element of 'Diversity' (0.15), but this is negligible (**Table 21**).

5.5.3 Limitations

This dietary diversity is measured by the valuable MDD-W indicator. However, it is noteworthy to acknowledge that there are some limitations. MDD-W assesses whether women consume at least five out of ten food groups. Yet, it does not consider the quantity and quality of the foods consumed, leaving the diet's true nutritional value and micronutrient adequacy unmeasured (FAO, 2021; 2024). Likewise, individuals who consume a wide variety of foods from all five required food groups may exhibit markedly different dietary food intake characteristics. This suggests the need for more advanced tools to evaluate the quality of diets, with an emphasis on improving sustainable food systems instead of only counting food groups. This could lead to better targeted agroecological interventions that improve dietary quality.

The study used a single 24-hour recall, which may not capture the full dietary diversity of women over a year. For a more accurate assessment, we recommend multiple recalls across different seasons (FAO, 2021; 2024). Moreover, it's important to consider the potential time lag in the effects of agroecological practices on dietary diversity. The benefits of such practices might not manifest immediately. This delay can be attributed to factors like crop maturation times, which dictate when new or more diverse food products become available (Hirvonen et al., 2015). Furthermore, changes in economic conditions or gradual shifts in dietary habits also contribute to this lag (Fiore et al., 2024). Therefore, immediate changes in agroecological practices might not quickly translate into observable improvements in dietary diversity, necessitating a longer-term perspective to fully access their impact (Niggli et al., 2023).

Focusing exclusively on women in dietary diversity assessments can introduce gender-specific biases, as men also play crucial roles in enhancing household nutrition. Men can support dietary diversity by reducing their consumption of food outside the home, particularly during food shortages, and instead using those funds for nutritious household purchases. They can also improve nutrition security by retaining part of the farm produce for home use rather than selling it all (Ambikapathi et al., 2021). Furthermore, increasing nutritional knowledge among men has been shown to positively impact the dietary diversity of the entire household, underscoring the need for inclusive nutrition education programs that target both genders (Oching et al., 2017).

Further, step 1 of the TAPE tool involves assessing ten elements through a set of statements rather than direct questions, which can be challenging for enumerators. This format requires enumerators to interpret and formulate their own questions to determine which statements are applicable. This complexity might restrict the tool's accessibility for smallholder farmers or local stakeholders who may lack the necessary technical background to effectively engage with the assessment process. This situation introduces a form of interpretation bias, where the outcome of the assessment could be influenced by the enumerator's personal understanding and the way they choose to phrase questions based on the provided statements. This bias can lead to inconsistencies in data collection and may affect the reliability and validity of the assessment results. Further, the technical issues during the data collection can have an impact on the outcomes of this study.

5.5.4 Future research

Research on the effects of agroecology on broader nutritional indicators, such as nutritional status, dietary patterns, and trends, as well as diet quality is needed (Kerr et al., 2021). These dietary elements have an impact on how the food system functions and how widely agroecological methods are adopted (Brouwer et al. 2021). Changing attitudes and beliefs may increase demand for traditional, locally grown, and agroecologically produced foods due to the growing demand for varied diets brought on by health concerns and consumer interest in sustainable eating. Even though diet quality is a key indicator of nutritional status, it does not give a complete picture when considering factors such as systemic inflammation, poor nutrient absorption, and other factors like high aflatoxins, poor water quality or poor sanitation and hygiene. If values can be linked to the implemented intervention and/or program, the collection of nutrition biomarkers through biological samples should be included (Zutphen et al., 2022).

In order to optimize dietary diversity assessments in alignment with agroecology, alternatives to the commonly used MDD-W must be considered. While MDD-W has made significant contributions to our understanding of micronutrient adequacy among women of reproductive age, emerging tools such as the Global Diet Quality Score (GDQS) and Dietary Species Richness (DSR) may provide broader insights into the integration of dietary diversity and sustainability (Bromage et al., 2021; Lachat et al., 2017).

The GDQS evaluates dietary quality based on the consumption of 27 food groups. Unlike MDD-W, which only measures diversity across food groups without considering the consumption of unhealthy foods, GDQS accounts for both the intake of beneficial nutrients and the avoidance of unhealthy ones. This dual focus makes GDQS a comprehensive tool for assessing dietary impacts on health beyond micronutrient adequacy, incorporating factors critical for NCDs prevention. Its comprehensive nature could be instrumental in designing agroecological interventions that aim not only to enhance food diversity but also to improve overall dietary quality and health outcomes at the community level (Bromage et al., 2021). Using the MDD-W and similar tools like the GDQS reveals a critical limitation in their practice of categorizing foods into predefined broad groups. This approach can mask the significant nutritional differences that exist within each food group. Consequently, such categorization can result in a simplified understanding of diets that may not accurately reflect the true nutritional complexity and variety of the foods consumed.

Unlike MDD-W and GDQS, which categorize foods into broad groups, DSR identifies individual species, providing a detailed snapshot of the actual biodiversity in a person's diet. This precision allows for an accurate accounting of what is being consumed, reflecting not only dietary diversity but also the ecological variety of the foods. Such detail is particularly pertinent to the principles of agroecology, which prioritize biodiversity and the sustainability of food systems. Furthermore, DSR's capability to reveal the variety of species consumed makes it invaluable for assessing how diverse agricultural practices influence dietary choices at a community level (Lachat et al., 2017). This offers a direct link between the environmental and nutritional dimensions, demonstrating how local ecosystems directly support human health.

In light of these considerations, both GDQS and DSR present promising avenues for future research in the context of agroecology. More research is necessary to fully explore their potential to offer a more comprehensive understanding of the connections among nutritional quality, dietary diversity and sustainability.

6. Conclusion

This research investigated the impact the of agroecological practices on dietary diversity in Vihiga County, Kenya. By using the TAPE tool and assessing the MDD-W indicator, the study provided insight into how agroecology influences nutritional outcomes.

Differences in the results of agroecological elements across defined CAET categories and between intervention (agroecological zones) and control groups (non-agroecological zones) were examined. The findings indicated significant differences across the ten agroecological elements. Notably, agroecological CAET categories generally performed better than non-agroecological. This difference was also pronounced between the intervention and control groups, underlining the effectiveness of targeted agroecological strategies.

In Vihiga County, most indicators across various dimensions displayed low correlations with the agroecological elements. However, the economic dimension showed the highest correlations. Specifically, diversity within agroecological systems significantly enhanced economic returns, underscoring the potential economic benefits of diversified agricultural practices. This suggests a need for more in-depth studies to better understand how agroecology can be optimized for improving sustainable food systems.

Although agroecological practices are aligned with enhanced dietary diversity in literature, the data from MDD-W did not demonstrate a strong correlation between agroecology elements and improved dietary outcomes. This suggests that while agroecology may contribute to more sustainable food systems, its direct impact on dietary diversity is less pronounced than expected.

The MDD-W indicator has been shown to be useful in evaluating the micronutrient adequacy of diets in various populations. While MDD-W has offered valuable insights into the dietary practices in Vihiga County, it doesn't seem to be able to adequately capture the nutritional adequacy and overall quality of diets in relation to agroecological practices in the context of this study. Given these findings, it is early to conclude definitively that MDD-W is unsuitable for assessing the dietary effects of agroecology. Instead, this study suggests that more research should be conducted to determine how this indicator can be adapted or supplemented to better reflect the specific dietary outcomes associated with agroecological practices. For future research, it is recommended to explore alternative indicators like the GDQS and DSR that may provide deeper insights into the dietary impacts of agroecological practices. Additionally, longitudinal studies could help in understanding the time-lagged effects of

agroecological practices on dietary diversity, capturing seasonal variations and longer-term dietary changes.

This research emphasizes that although agroecology has potential for improving sustainability and could influence dietary patterns, the direct connections to dietary diversity are limited. The modest progress in the agroecological transition, as evidenced by the average CAET score of 47.80%, calls for continued efforts in policy-making and practical interventions. The newly incorporated agroecology policy in Vihiga County's development plan is a promising step toward addressing these challenges.
In order to fully realize the potential of agroecological approaches to improve dietary outcomes, more research is needed in different areas, as this study highlights. Overall, it is an important first step toward improving understanding of the role that agroecology can play in strengthening sustainable, diverse, and nutritious food systems.

References

Agricultural Sector Development Support Program (ASDSP). (2014). Vihiga County.

Alliance for Food Sovereignty in Africa (AFSA). (2020). Kenyan National Climate Change Gaps and Mainstreaming Kenya. 1–44.

Alliance of Bioversity International and CIAT. (2023). Farm resilience, healthy diets & sustainable food system in Vihiga County. Retrieved from https://alliancebioversityciat.org/stories/farm-resilience-healthy-diets-sustainable-food-system-vihiga-county

Altieri, M.A. (1995). Agroecology: The Science of Sustainable Agriculture. Boulder CO: Westview Press.

Ambikapathi, R., Passarelli, S., Madzorera, I., Canavan, C. R., Noor, R. A., Abdelmenan, S., Tewahido, D., Tadesse, A. W., Sibanda, L., Sibanda, S., Munthali, B., Madzivhandila, T., Berhane, Y., Fawzi, W., & Gunaratna, N. S. (2021). Men's nutrition knowledge is important for women's and children's nutrition in Ethiopia. Maternal & child nutrition, 17(1), e13062. https://doi.org/10.1111/mcn.13062

Anderson, C. R., Maughan, C., & Pimbert, M. P. (2019). Transformative agroecology learning in Europe: building consciousness, skills and collective capacity for food sovereignty. Agriculture and Human Values, 36(3), 531–547. https://doi.org/10.1007/s10460-018-9894-0

Atta-Krah K; Chotte J-L; Gascuel C; Gitz V; Hainzelin E; Hubert B; Quintero M; Sinclair F. (eds). (2021). Agroecological transformation for sustainable food systems. Insight on France-CGIAR research. Les dossiers d'Agropolis International, 26. Agropolis International, Montpellier, France. 148 p. https://doi.org/10.23708/fdi:010082500

Barrios, E., Gemmill-Herren, B., Bicksler, A., Siliprandi, E., Brathwaite, R., Moller, S., Batello, C., & Tittonell, P. (2020). The 10 Elements of Agroecology: enabling transitions towards sustainable agriculture and food systems through visual narratives. Ecosystems and People, 16(1), 230–247. https://doi.org/10.1080/26395916.2020.1808705

Berti, P. R., Krasevec, J., & Fitz Gerald, S. (2004). A review of the effectiveness of agriculture interventions in improving nutrition outcomes. Public Health Nutrition, 7(5), 599–609. https://doi.org/10.1079/phn2003595

Biovision (2019). 13 principles of agroecology. Retrieved from https://www.agroecology-pool.org/13aeprinciples/

Bliss, K. (2017). Cultivating biodiversity: a farmer's view of the role of diversity in agroecosystems. Biodiversity 18, 102–107. https://doi.org/10.1080/ 14888386.2017.1361866

Bromage, S., Batis, C., Bhupathiraju, S. N., Fawzi, W. W., Fung, T. T., Li, Y., Deitchler, M., Angulo, E., Birk, N., Castellanos-Gutiérrez, A., He, Y., Fang, Y., Matsuzaki, M., Zhang, Y., Moursi, M., Gicevic, S., Holmes, M. D., Isanaka, S., Kinra, S., Sachs, S. E., … Willett, W. C. (2021). Development and Validation of a Novel Food-Based Global Diet Quality Score (GDQS). The Journal of nutrition, 151(12 Suppl 2), 75S–92S. https://doi.org/10.1093/jn/nxab244

Caron P, Ferrero y de Loma-osorio G, Nabarro D, Hainzelin E, Guillou M, Andersen I, Arnold T, Astralaga M, Beukeboom M, Bickersteth S, et al. (2018). Food systems for sustainable development: proposals for a profound four-part transformation. Agron Sustain Dev. 38:41. doi:10.1007/s13593-018-0519-1.

Chumba, R. K. B., Ogemah, V., Oulu, M., Muyekho, F. N., Wambui, C. C., Aluso, L., & Mugendy, M. M. (2024). Modeling a Sub-National Agroecology Policy for Sustainable Agriculture: The Case of Vihiga County, Kenya. Agriculture, (5), 2574-2599.

Clark, W. C., Van Kerkhoff, L., Lebel, L., & Gallopin, G. C. (2016). Crafting usable knowledge for sustainable development. Proceedings of the National Academy of Sciences of the United States of America, 113(17), 4570–4578. https://doi.org/10.1073/pnas.1601266113

County Government of Vihiga. (2013). Republic of Kenya Vihiga County First County Integrated Plan 2013-2017.

County Government of Vihiga. (2018). Republic of Kenya Vihiga County Second County Integrated Development Plan 2018-2022.

County Government of Vihiga. (2023). Republic of Kenya Vihiga County Third County Integrated Plan 2023-2027.

Deaconu, A., Berti, P. R., Cole, D. C., Mercille, G., & Batal, M. (2021). Agroecology and nutritional health: A comparison of agroecological farmers and their neighbours in the Ecuadorian highlands. Food Policy, 101. https://doi.org/10.1016/j.foodpol.2021.102034

Delisle, H. F. (2008). Poverty: The double burden of malnutrition in mothers and the intergenerational impact. Annals of the New York Academy of Sciences, 1136, 172–184. https://doi.org/10.1196/annals.1425.026

Duffy, C., Toth, G. G., Hagan, R. P. O., McKeown, P. C., Rahman, S. A., Widyaningsih, Y., Sunderland, T. C. H., & Spillane, C. (2021). Agroforestry contributions to smallholder farmer food security in Indonesia. Agroforestry Systems, 95(6), 1109–1124. https://doi.org/10.1007/s10457-021-00632-8

FAO and Government of Kenya. (2018). Kenyan Food Recipes. A recipe book of common mixed dishes with nutrient value. Nairobi, FAO. 349 pp. http://www.fao.org/3/I8897EN/I8897en.pdf

FAO and WHO. (2019). Sustainable healthy diets – Guiding principles. Rome.

FAO. (2005). Kenya Nutrition Profile-“Food and Nutrition Division”.

FAO. (2012). Voluntary guidelines on the responsible governance of tenure of land, fisheries and forests in the context of national food security. Rome: Food and Agriculture Organization of the United Nations.

FAO. (2018a). FAO's work on agroecology - A pathway to achieving the SDGs, FAO Report I9021EN/1/03.18 http://www.fao.org/3/i9021en/i9021en.pdf

FAO. (2018b). The 10 elements of Agroecology Guiding the transition to sustainable food and agricultural systems. FAO, 15. http://www.fao.org/3/I9037EN/i9037en.pdf

FAO. (2019). Tool for Agroecology Performance Evaluation (TAPE) - Test version. Rome.

FAO. (2021). Minimum dietary diversity for women. https://doi.org/10.4060/cb3434en

FAO. (2024). Minimum Dietary Diversity for Women: Frequently Asked Questions. 20.

Feliciano, D. (2019). A review on the contribution of crop diversification to Sustainable Development Goal 1 “No poverty” in different world regions. Sustainable Development, 27(4), 795–808. https://doi.org/10.1002/sd.1923

Fiore, V., Borrello, M., Carlucci, D., Giannoccaro, G., Russo, S., Stempfle, S., & Roselli, L. (2024). The socio-economic issues of agroecology: A scoping review. Agricultural and Food Economics, 12 (Article 16).

Fred J. (2016). Issues Affecting the agricultural Sector in Vihiga County. https://sokodirectory.com/2016/03/issues-affecting-the-agricultural-sector-in-vihiga-county/

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

Gibson, R. S., Ruth Charrondiere, U., & Bell, W. (2017). Measurement errors in dietary assessment using self-reported 24-hour recalls in low-income countries and strategies for their prevention. Advances in Nutrition, 8(6), 980–991. https://doi.org/10.3945/an.117.016980

Gliessman S.R. (2007). Agroecology: the ecology of sustainable food sys-tems, CRC Press, Taylor & Francis, New York, USA, 384 p.

Gliessman, S. (2018). The co-creation of agroecological knowledge. Agroecology and Sustainable Food Systems, 42(1), 1. https://doi.org/10.1080/21683565.2017.1289727

Gliessman, S. R. (2014). Agroecology and Sustainable Food Systems. In Agroecology and Sustainable Food Systems (Issue 3).

Gliessman, S.R. (2016). Transforming food systems with agroecology. Agroecology and Sustainable Food Systems, 40(3): 187–189.

Global Nutrition Report. (2020). 2020 Global Nutrition Report: Action on equity to end malnutrition. Development Initiatives. https://globalnutritionreport.org/reports/2020-global-nutrition-report/

Global Nutrition Report. (2022). 2022 Global Nutrition Report: 2022 Global Nutrition Report: Stronger commitments for greater action. https://globalnutritionreport.org/reports/2022-global-nutrition-report/

Hanley-cook, G. T., Tung, J. Y. A., Sattamini, I. F., Marinda, P. A., Thong, K., Zerfu, D., Kolsteren, P. W., Tuazon, M. A. G., & Lachat, C. K. (2020). Minimum dietary diversity for women of reproductive age (MDD-W) data collection: Validity of the list-based and open recall methods as compared to weighed food record. Nutrients, 12(7), 1–13. https://doi.org/10.3390/nu12072039

Hawk, A. (2006). The great disease enemy, Kak'ke (beriberi) and the Imperial Japanese Army. Military Medicine, 171(4), 333–339. https://doi.org/10.7205/MILMED.171.4.333

Hickson M. Smith S. & British Dietetic Association. (2018). Advanced nutrition and dietetics in nutrition support. John Wiley & Sons. Retrieved January 11 2024 from https://public.ebookcentral.proquest.com/choice/publicfullrecord.aspx?p=5240568.

Hirvonen, K., Taffesse, A. S., & Hassen, I. W. (2015). Seasonality and household diets in Ethiopia. International Food Policy Research Institute.

HLPE. (2016). Sustainable agricultural development for food security and nutrition: What roles for livestock? Committee on World Food Security. A Report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, July, 140.

HLPE. (2019). Agroecological and other innovative approaches for sustainable agriculture and food systems that enhance food security and nutrition. A Report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, July, 162.

International Food Policy Research Institute (IFPRI). (2014). Global Nutrition Report: Actions and Accountability to Accelerate the World's Progress on Nutrition, Washington, DC. In Global Nutrition Report 2014.

Intersectoral Forum on Agrobiodiversity and Agroecology (IFSAA). (2004). Policy and Law TWG. Retrieved from https://isfaa.ke/policy-and-law-twg/

Jaetzold R., Schmidt H., Hornetz B. & Shisanya C. (2010). Farm Management Handbook of Kenya. Gesellschaft für Internationale Zusammenarbeit, vol. 2. Brookpak Printing & Supplies, Nairobi, Kenya.

Kamau, J.W., Stellmacher, T., Biber-Freudenberger, L. & Borgemeister, C. (2018). Organic and conventional agriculture in Kenya: A typology of smallholder farms in Kajiado and Murang'a counties. Journal of Rural Studies, 57: 171–185.

Kangmennaang J, Bezner Kerr R, Lupafya E, Dakishoni L, Katundu M, Luginaahm I (2017). Impact of a participatory agroecological devel-opment project on household wealth and food security in Malawi. Food Secur 9:561–576. https://doi.org/10.1007/s12571-017-0669-z

Kenya National Bureau of Statistics (KNBS). (2019). Kenya population and housing census. Vol 1. Population by county and sub-county. Kenya National Bureau of Statistics, Nairobi, Kenya.

Kenya National Bureau of Statistics (KNBS). (2023). Kenya population and housing census. Vol 1. Population by county and sub-county. Kenya National Bureau of Statistics, Nairobi, Kenya.

Kerr Bezner, R., Madsen, S., Stüber, M., Liebert, J., Enloe, S., Borghino, N., Parros, P., Mutyambai, D. M., Prudhon, M., & Wezel, A. (2021). Can agroecology improve food security and nutrition? A review. Global Food Security, 29(March). https://doi.org/10.1016/j.gfs.2021.100540

Kerr, R. B., Kangmennaang, J., Dakishoni, L., Nyantakyi-Frimpong, H., Lupafya, E., Shumba, L., et al. (2019). Participatory agroecological research on climate change adaptation improves smallholder farmer household food security and dietary diversity in Malawi. Agric. Ecosyst. Environ. 279, 109–121. doi: 10.1016/j.agee.2019.04.004

Kihima, M. V. (2015). The Impact Land Sub-division and Fragmentaion on Rural Development: a Case Study of Vihiga County.

Kindt, R., Van Damme, P., & Simons, A. J. (2006). Patterns of species richness at varying scales in western Kenya: Planning for agroecosystem diversification. Biodiversity and Conservation, 15(10), 3235–3249. https://doi.org/10.1007/s10531-005-0311-9

Kirimi, L., Sitko, N., Jayne, T. S., Karin, F., Muyanga, M., Sheahan, M., Flock, J., & Bor, G. (2011). A farm gate-to-consumer value chain analysis of Kenya ' s maize marketing system., The Michigan State University (MSU) International Development Working Paper No. 111.

Koppmair, S., Kassie, M., & Qaim, M. (2017). Farm production, market access and dietary diversity in Malawi. Public Health Nutrition, 20(2), 325–335. https://doi.org/10.1017/S1368980016002135

Lucantoni D., Mottet A., Bicksler A., De Rosa F., Scherf B., Scopel E., López-Ridaura S., GemmilHerren B., Bezner Kerr B., Sourisseau J.-M., Petersen P., Chotte J.-L., Loconto A. & Tittonell P. (2021) Évaluation des transitions vers des systèmes agricoles et alimentaires durables: un outil pour l'évaluation des performances agroécologiques (TAPE). Agronomie et Politique Agricole Commune, Revue AE&S 11-1

Lucantoni, D., Thulo, M., Makhoebe, L. M., Mottet, A., Bicksler, A., & Sy, M. R. (2022). Report on the use of the Tool for Agroecology Performance Evaluation (TAPE) in Lesotho in the context of the Restoration of Landscape and Livelihoods Project (ROLL): Results and analysis. Food and Agriculture Organization of the United Nations.

Ministry of health. (2015). Kenya Stepwise Survey for Non-Communicable Diseases Risk Factors 2015 Report. Nairobi.

Ministry of Health. (2017). National Guidelines for Healthy Diets and Physical Activity. Government of Kenya. Nairobi.

Mkuu, R. S., Epnere, K., & Chowdhury, M. A. B. (2018). Prevalence and predictors of overweight and obesity among Kenyan women. Preventing Chronic Disease, 15(4), 1–10. https://doi.org/10.5888/pcd15.170401

Mohamed, S., Wambiya, E., Kisia, L., & Osindo, J. (2021). The cost of eating healthy in Kenya.
Mohanja, H. (2014). Food and Nutrition Scenario of Kenya. American Journal of Food and Nutrition, 2(56218), 28–38. t https://mpra.ub.uni-muenchen.de/56218/

Mottet A, Cluset R, Lucantoni D, et al. (2023). Tool for agroecology performance evaluation (TAPE). In: TAPE Validation Workshop, Rome, 2–3 May 2023. Unpublished.

Mottet, A., Bicksler, A., Lucantoni, D., De Rosa, F., Scherf, B., Scopel, E., López-Ridaura, S., Gemmil-Herren, B., Bezner Kerr, R., Sourisseau, J. M., Petersen, P., Chotte, J. L., Loconto, A., & Tittonell, P. (2020). Assessing Transitions to Sustainable Agricultural and Food Systems: A Tool for Agroecology Performance Evaluation (TAPE). Frontiers in Sustainable Food Systems, 4 (December), 1–21. https://doi.org/10.3389/fsufs.2020.579154

Mutui E. and Aluso L. (2023). Farm resilience and healthy diets for a sustainable food system in Vihiga County. alliancebiodiversityciat. Retrieved December 18,2023 from https://alliancebioversityciat.org/stories/farm-resilience-healthy-diets-sustainable-food-system-vihiga-county

National Agricultural and Rural Inclusive Growth Project (NARIGP), Government of Kenya, & World Bank. (2020). Kenya County Climate Risk Profile: Vihiga County.

Niggli, U., Sonnevelt, M., & Kummer, S. (2023). Pathways to Advance Agroecology for a Successful Transformation to Sustainable Food Systems. Science and Innovations for Food Systems Transformation, 341–359. https://doi.org/10.1007/978-3-031-15703-5_18

Nyantakyi-Frimpong, H., Mambulu, F.N., Bezner Kerr, R., Luginaah, I., Lupafya, E., (2016). Agroecology and sustainable food systems: participatory research to improve food security among HIV-affected households in northern Malawi. Soc. Sci. Med. 164, 89–99. https://doi.org/10.1016/j.socscimed.2016.07.020.

Ochieng, J., Afari-Sefa, V., Lukumay, P. J., & Dubois, T. (2017). Determinants of dietary diversity and the potential role of men in improving household nutrition in Tanzania. PloS one, 12(12), e0189022. https://doi.org/10.1371/journal.pone.0189022

Omwenga A. and Munyaka L. (2023). Murang'a County Government Enacts An Agro Ecology Policy And ACT. Kenyanews. Retrieved December 20, 2023, from https://www.kenyanews.go.ke/muranga-county-government-enacts-an-agro-ecology-policy-and-act/

Paracchini, M. ., Wezel, A., Madsen, S., Stewart, B., Karuga, J., Attard, P., Reme, L., Kerr, R. B., Maes, 0., & Zingari, P. (2022). Agroecological practices supporting food production and reducing food insecurity in developing countries. Volume 2. A study on scientific literature in nine countries. In JRC Technical Report. https://doi.org/10.2760/82475

Ruel, M. T., & Alderman, H. (2013). Nutrition-sensitive interventions and programmes: How can they help to accelerate progress in improving maternal and child nutrition? The Lancet, 382(9891), 536–551. https://doi.org/10.1016/S0140-6736(13)60843-0

Schipanski, M. E., MacDonald, G. K., Rosenzweig, S., Chappell, M. J., Bennett, E. M., Kerr, R. B., Blesh, J., Crews, T., Drinkwater, L., Lundgren, J. G., & Schnarr, C. (2016). Realizing resilient food systems. BioScience, 66(7), 600–610. https://doi.org/10.1093/biosci/biw052

Sibhatu, K. T., Krishna, V. V., & Qaim, M. (2015). Production diversity and dietary diversity in smallholder farm households. Proceedings of the National Academy of Sciences of the United States of America, 112(34), 10657–10662. https://doi.org/10.1073/pnas.1510982112

Silici, L. (2014). Agroecology. What it is and What it has to offer. International Institute for Environment and Development, London, June, 1–27.

Smith, L., and Haddad, L. (2015). Reducing child undernutrition: past drivers and priorities for the post-MDG Era. World Dev. V 68, 180–204. doi: 10.1016/j.worlddev.2014.11.014

Snapp SS, Blackie MJ, Gilbert RA, Bezner Kerr R, Kanyama-Phiri GY (2010). Biodiversity can support a greener revolution in Africa. Proc Natl Acad Sci 107(48):20840–20845. https://doi.org/10.1073/pnas.1007199107

United Nations (2023). Progress towards the Sustainable Development Goals: towards a rescue plan for people and planet Report of the Secretary-General (special edition).

United Nations. (2008). Organic Agriculture and Food Security in Africa. United Nations: New York & Geneva

Van Zutphen, K. G. Van, Berg, S. Van Den, Gavin-smith, B., Imbo, E., Kraemer, K., Monroy-gomez, J., Pannatier, M., Prytherch, H., Six, J., Thoennissen, C., Winter, S., & Barjolle, D. (2022). Nutrition as a driver and outcome of agroecology. 3(December), 990–996. https://doi.org/10.1038/s43016-022-00631-7

Vernooy, R., Sthapit, B., Galluzzi, G., & Shrestha, P. (2014). The multiple functions and services of community seedbanks. Resources, 3(4), 636–656. https://doi.org/10.3390/resources3040636

Waithaka, M. M., Thornton, P. K., Shepherd, K. D., & Ndiwa, N. N. (2007). Factors affecting the use of fertilizers and manure by smallholders: The case of Vihiga, western Kenya.

Wezel, A., Francis, C.A., Bellon, S., Vallod, D. (2009). Agroecology as a science, a movement or a practice: A review. Agronomy for Sustainable Development 29: 503–515.

Wezel, A., Herren, B.G., Kerr, R.B. Barrios, E., Gonçalves A.L.R., Sinclair, F. (2020). Agroecological principles and elements and their implications for transitioning to sustainable food systems. A review. Agron. Sustain. Dev. 40, 40 (2020). https://doi.org/10.1007/s13593-020-00646-z

Wittman, H., & James, D. (2022). Land governance for agroecology. Elementa, 10(1), 1–19. https://doi.org/10.1525/elementa.2021.00100

World Health Organization. (2003). Diet, nutrition and the prevention of chronic diseases: report of a joint WHO/FAO expert consultation, Geneva, 28 January - 1 February 2002. World Health Organization. https://iris.who.int/handle/10665/42665

World Health Organization. (2020). Healthy diet. Retrieved from https://www.who.int/initiatives/behealthy/healthy-diet

Appendices

Appendix A: Step 0: Description systems and context, Tool for Agroecology Performance Evaluation (TAPE) questionnaire (FAO, 2019)

1. **Location**
   a. Selection your region
      - ❑ Sub-Saharan Africa
      - ❑ Near East & Noth Africa
      - ❑ Asia & Pacific
      - ❑ Europe
      - ❑ Latin America & Caribbean
      - ❑ North America

   b. Select your country:
   c. Location (Region, Province):
   d. Location (municipality, District):
2. **Please take GPS of this location**
   - Latitude (x.y °):
   - Longitude (x.y °):
   - Altitude (m):
   - Accuracy (m):
3. **Type of production system:**
4. **Please assign a name to the system assessed *(You use the family name)*:**

   What is the ethnicity of the components of the household (if applicable or relevant to the study):
5. **How many people live in the household?**
   - Men *(35 years and over):*
   - Women *(35 years and over):*
   - Male young household members *(15-34 years):*
   - Female young household members *(15-34 years):*
   - Children *(younger than 15):*
6. **How many of these work in the agricultural production of the system assessed? *(If some of these works only part time in the agricultural production, count them half (0.5))***
   - Men (35 years and over):
   - Women (35 years and over):
   - Male young household members (15-34 years):
   - Female young household members (15-34 years):

- Children (younger than 15):

7. Did any external worker in your farm during the last 12 months?

- ❑ Yes
- ❑ No

Productive activities RODUCTIVE ACITIVITIES

8. Area

a. Total area under agricultural production (ha):

b. Total area under permanent pasture (ha) *(excluding common land):*

c. Total area under natural vegetation (ha) *(excluding common land):*

d. Approximative area of common pastures available *(consider only common lands):*

9. What are the productive agricultural outputs? *(Select as many as necessary)*

- ❑ Cereals
- ❑ Leguminous
- ❑ Roots and tubers
- ❑ Vegetables
- ❑ Fruit trees
- ❑ Timber trees
- ❑ Cattle
- ❑ Small ruminants
- ❑ Pigs
- ❑ Poultry
- ❑ Animal products
- ❑ Fishery and aquaculture
- ❑ Other:

Appendix B: Step 1 : Characterisation of the Agroecological Transitions (CAET), Tool for Agroecology Performance Evaluation (TAPE) questionnaire (FAO, 2019)

	DIVERSITY				
INDEX	**0**	**1**	**2**	**3**	**4**
Crops	Monoculture (or no crops cultivated).	One crop covering more than 80% of cultivated area.	Two or three crops with significant cultivated area.	More than 3 crops with significant cultivated area adapted to local climatic conditions.	More than 3 crops of different varieties adapted to local conditions and spatially diversified farm with multi-, poly-, inter-cropping.
Animals (including fish and insects)	No animals raised.	No animals raised.	Two or three species, with few animals.	More than 3 species with significant number of animals.	More than 3 species with different breeds well adapted to local climatic conditions.
Trees	No trees (nor other perennials).	Few trees (and/or other perennials) of one species only.	Some trees (and/or other perennials) of more than one species.	Significant number of trees (and/or other perennials) of different species.	High number of trees (and/or other perennials) of different species integrated within the productive system.
Diversity of economic activities, products and services	Only one activity producing income (e.g. selling one crop only).	Two or three activities producing income (e.g. selling 2 crops or one crop and one type of animal).	More than 3 activities Monoculture that produce income.	More than 3 activities producing income and at least one service provided (e.g. processing products on the farm, ecotourism, transport of agricultural goods, training, etc.).	More than 3 activities producing income and several services provided.

SYNERGIES

INDEX	0	1	2	3	4
Crop-livestock-aquaculture integration	No integration: animals, including fish, are fed with purchased feed and their manure is not used for soil fertility; or no animals in the agroecosystem.	Low integration: animals are mostly fed with purchased feed; their manure is used as fertilizer.	Medium integration: animals are mostly fed with feed produced on the farm and/or grazing; their manure is used as fertilizer.	High integration: animals are mostly fed with feed produced on the farm, crop residues and by-products and/or grazing, their manure is used as fertilizer, and they provide at least one service (e.g. traction).	Complete integration: animals are exclusively fed with feed produced on the farm, crop residues and by-products and/or grazing, all their manure is recycled as fertilizer and they provide more than one service (food, products, traction, etc.).
Soil-plants system management	Soil is bare after harvest. No intercropping. No crop rotations (or rotational grazing systems). Heavy soil disturbance (biological, chemical or mechanical).	Less than 20% of the arable land is covered with residues or cover crops. More than 80% of the crops are produced in mono and continuous cropping (or no rotational grazing).	50% of soil is covered with residues or cover crops. Some crops are rotated or intercropped (or some rotational grazing is carried out).	More than 80% of soil is covered with residues or cover crops. Crops are rotated regularly or intercropped (or rotational grazing is systematic). Soil disturbance is minimized.	All the soil is covered with residues or cover crops. Crops are rotated regularly, and intercropping is common (or rotational grazing is systematic). Little or no soil disturbance .
Integration with trees (agroforestry, silvopastoralism, agrosilvopastoralism)	No integration: trees (and other perennials) don't have a role for humans or in crop or animal production.	Low integration: small number of trees (and other perennials) only provide one product (e.g. fruits, timber, forage, medicinal or biopesticides substances…) or service (e.g. shade for animals, increased soil fertility, water retention, barrier to soil erosion…) for humans crops and/or animals.	Medium integration: significant number of trees (and other perennials) provide at least one product or service.	High integration: significant number of trees (and other perennials) provide several products and services.	Complete integration: many trees (and other perennials) provide several products and services.
Integration with trees (agroforestry, silvopastoralism, agrosilvopastoralism)	No connectivity: high uniformity within and outside the agroecosystem, no semi-natural environments, no zones of ecological compensation.	Low connectivity: a few isolated elements can be found in the agroecosystem, such as trees, shrubs, natural fences, a pond or a small zone of ecological compensation.	Medium connectivity: several elements are adjacent to crops and/or pastures or a large zone of ecological compensation.	Significant connectivity: several elements can be found in between plots of crops and/or pastures or several zones of ecological compensation (trees, shrubs, natural vegetation, pastures, hedges, channels, etc.).	High connectivity: the agroecosystem presents a mosaic and diversified landscape, many elements such as trees, shrubs, fences or ponds can be found in between each plot of cropland or pasture, or several zones of ecological compensation.

	EFFICIENCY				
INDEX	0	1	2	3	4
Use of external inputs	All inputs are purchased from the market.	The majority of the inputs is purchased from the market.	Some inputs are produced on farm/within the agroecosystem or exchanged with other members of the community.	The majority of the inputs is produced on farm/within the agroecosystem or exchanged with other members of the community.	All inputs are produced on farm/within the agroecosystem or exchanged with other members of the community.
Management of soil fertility	Synthetic fertilisers are used regularly on all crops and/or grasslands (or no fertilizers are used for lack of access, but no other management system is used).	Synthetic fertilizers are used regularly on most crops and some organic practices (e.g. manure or compost) are applied to some crops and/or grasslands.	Synthetic fertilisers are used on a few specific crops only. Organic practices are applied to the other crops and/or grasslands.	Synthetic fertilisers are only used exceptionally. A variety of organic practices are the norm.	No synthetic fertilisers are used, soil fertility is managed only through a variety of organic practices.
Management of pests & diseases	Chemical pesticides and drugs are used regularly for pest and disease management. No other management is used.	Chemical pesticides and drugs are used for a specific crop/animal only. Some biological substances and organic practices are applied sporadically.	Pests and diseases are managed through organic practices, but chemical pesticides are used only in specific and very limited cases.	No chemical pesticides and drugs are used. Biological substances are the norm.	No chemical pesticides and drugs are used. Pests and diseases are managed through a variety of biological substances and prevention measures.
Productivity and household's needs	Household's needs are not met for food nor for other essentials.	Production covers only household's needs for food. No surplus to generate income.	Production covers household's needs for food and surplus generates cash to buy essentials and to have sporadic savings .	Production covers household's needs for food and surplus generates cash to buy essentials and to have sporadic savings.	All household's needs are met both for food and for cash to buy all essentials needed and to have regular savings.

	RECYCLING				
INDEX	0	1	2	3	4
Recycling of biomass and nutrients	Residues and by-products are not recycled (e.g. left for decomposition or burnt). Large amounts of waste are discharged or burnt.	A small part of the residues and by-products is recycled (e.g. crop residues as animal feed, use of manure as fertilizer, production of compost from manure and household waste, green manure). Waste is discharged or burnt .	More than half of the residues and by-products is recycled. Some waste is discharged or burnt.	Most of the residues and by-products are recycled. Only a little waste is discharged or burnt.	Most of the residues and by-products are recycled. Only a little waste is discharged or burnt.
Water Saving	No equipment nor techniques for water harvesting or saving.	One type of equipment for water harvesting or saving (e.g. drip irrigation, tank).	One type of equipment for water harvesting or saving and use of one practice to limit water use (e.g. timing irrigation, cover crops).	One type of equipment for water harvesting or saving and various practices to limit water use (including choice of crops that need less water).	Several types of equipment for water harvesting or saving and various practices to limit water use (including choice of crops that need less water).
Management of seeds and breeds	All seeds and/or animal genetic resources (e.g. chicks, young animals, semen) are purchased from the market.	More than 80% of seeds/animal genetic resources are purchased from the market.	About half of the seeds are self-produced or exchanged, the other half is purchased from the market. About half of the breeding is done with neighbouring farms.	The majority of seeds/animal genetic resources are self-produced or exchanged. Some specific seeds are purchased from the market.	All seeds/animal genetic resources are self-produced, exchanged with other farmers or managed collectively, ensuring enough renewal and diversity.
Renewable energy use and production	No renewable energy is used nor produced.	The majority of the energy is purchased from the market. A small amount is self-produced (animal traction, wind, turbine, hydraulic, biogas, wood…).	Half of the energy used is self-produced, the other half is purchased.	Significant production of renewable energy, negligible use of fuel and other non-renewable sources.	All of the energy used is renewable and/or self-produced. Household is self-sufficient for energy supply, which is guaranteed at every time. Use of fossil fuel is negligible.

RESILIENCE

INDEX	0	1	2	3	4
Stability of income/ production and capacity to recover from perturbations	Income is decreasing year after year; production is highly variable despite constant level of inputs and there is no capacity to recover after shocks/perturbations.	Income is on decreasing trend, production is variable from year to year (with constant inputs), or vice-versa. There is little capacity to recover after shocks/perturbations.	Income is overall stable, but production is variable from year to year (with constant inputs), or vice-versa. Income and production mostly recover after shocks/perturbations.	Income is stable and production varies little from year to year (with constant inputs), or vice-versa. Income and production mostly recover after shocks/perturbations.	Income and production are stable or increasing over time. They fully and quickly recover after shocks/perturbations.
Existence of social mechanisms to reduce vulnerability	No access to credit, no insurance, no community support mechanisms.	Community is not very supportive and its capacity to help aftershocks is very limited. And/or access to credit and insurance is limited.	Community is supportive but its capacity to help aftershocks is limited. And/or access to credit is available but hard to obtain in practice. Insurance is rare and does not allow for complete coverage from risks.	Community is very supportive for both men and women but its capacity to help aftershocks is limited. And/or access to credit is available and insurance covers only specific products/risks.	Community is highly supportive for both men and women and can significantly help aftershocks. And/or access to credit is almost systematic and insurance covers most of production.
Environmental resilience and capacity to adapt to climate change	Local environment is highly prone to climatic shocks and the system has little capacity to adapt to climate change.	Local environment suffers from climatic shocks and the system has little capacity to adapt to climate change.	Local environment can suffer from climatic shocks, but the system has a good capacity to adapt to climate change.	Local environment can suffer from climatic shocks, but the system has a strong capacity to adapt to climate change.	Local environment has a strong natural capital base, climatic shocks are rare, and the system has a strong capacity to adapt to climate change.

CULTURE AND FOOD TRADITIONS

INDEX	0	1	2	3	4
Appropriate diet and nutrition awareness	Systematic insufficient food to meet nutritional needs and lack of awareness of good nutritional practices.	Periodic insufficient food to meet nutritional needs and/or diet is based on a limited number of food groups. Lack of awareness of good nutritional practices.	Overall food security over time, but insufficient diversity in food groups. Good nutritional practices are known but not always enforced.	Food is sufficient and diverse. Good nutritional practices are known but not always enforced.	Food is sufficient and diverse. Good nutritional practices are known but not always enforced.
Local or traditional (peasant/indigenous) identity and awareness	No local or traditional (peasant / indigenous) identity felt.	Little awareness of local or traditional identity.	Local or traditional identity felt in part, or that concerns only part of the household.	Good awareness of local or traditional identity and respect of traditions or rituals overall.	Local or traditional identity strongly felt and protected, high respect for traditions and/or rituals.
Use of local varieties/ breeds and traditional (peasant & indigenous) knowledge for food preparation	No use of local varieties/breeds nor traditional knowledge for food preparation.	A majority of exotic/introduced varieties/breeds are consumed, or there is little use of traditional knowledge and practices for food preparation.	Both local and exotic/introduced varieties/breeds are produced and consumed. Local or traditional knowledge and practices for food preparation are identified but not always applied.	The majority of the food consumed comes from local varieties/breeds and traditional knowledge and practices for food preparation are implemented.	A number of local varieties/breeds are produced and consumed. Traditional knowledge and practices for food preparation are identified, applied and recognised in official frameworks and/or specific events.

CO-CREATION AND SHARING OF KNOWLEDGE

INDEX	0	1	2	3	4
Social mechanisms for the horizontal creation and transfer of knowledge and good practices	No social mechanisms for co-creation and transfer of knowledge are available to producers.	At least one social mechanism for the co-creation and transfer of knowledge exists but does not function well and/or is not used in practices.	At least one social mechanism for the co-creation and transfer of knowledge exists and is functioning but is not used to share knowledge on agroecology specifically.	One or several social mechanisms for the co-creation and transfer of knowledge exist, are functioning and are used to share knowledge on agroecology, including women.	Several well established and functioning social mechanisms for the co-creation and transfer of knowledge are available and widespread within the community, including women.
Access to agroecological knowledge and interest of producers in agroecology	Lack of access to agroecological knowledge: principles of agroecology are unknown to producers.	Principles of agroecology are mostly unknown to producers and/or there is little trust in them.	Some agroecological principles are known to producers and there is interest in spreading the innovation, facilitating knowledge sharing within and between communities and involving younger generations.	Agroecology is well known, and producers are willing to implement innovations, facilitating knowledge sharing within and between communities and involving younger generations, including women and younger generations.	Widespread access to agroecological knowledge of both men and women: producers are well aware of the principles of agroecology and eager to apply them, facilitating knowledge sharing within and between communities and involving younger generations .
Participation of producers in networks and grassroot organizations	Widespread access to agroecological knowledge of both men and women: producers are well aware of the principles of agroecology and eager to apply them, facilitating knowledge sharing within and between communities and involving younger generations.	Producers have sporadic relations with their local community and rarely participate in meetings and grass-root organisations.	Producers have sporadic relations with their local community and rarely participate in meetings and grass-root organisations.	Producers are well interconnected with their local community and often participate in the events of their grassroot organisations, including women.	Producers are well interconnected with their local community and often participate in the events of their grassroot organisations, including women.

HUMAN AND SOCIAL VALUES

INDEX	0	1	2	3	4
Women's empowerment	Women do not normally have a voice in decision making, not in the household nor in the community. No organisation for women empowerment exists.	Women may have a voice in their household but not in the community. And/or one form of women association exists but is not fully functional.	Women can influence decision making, both at household and community level, but are not decision makers. They don't have access to resources. And/or some forms of women associations exist but are not fully functional.	Women take full part in decision making processes but still don't have full access to resources. And/or women organisations exist and are used.	Women are completely empowered in terms of decision making and access to resources. And/or women organisations exist, are functional and operational.
Labour (productive conditions, social inequalities)	Women are completely empowered in terms of decision making and access to resources. And/or women organisations exist, are functional and operational.	Working conditions are hard, workers have average wages for the local context and may be exposed to risks.	Agriculture is mostly based on family farming, but producers have limited access to capital and decision-making processes. Workers have the minimum decent labour conditions.	Agriculture is mostly based on family farming and producers (both men and women) have access to capital and decision-making processes. Workers have decent labour conditions.	Agriculture is based on family farmers which have full access to capital and decision-making processes in gender equity. There is a social and economic proximity between farmers and employees.
Youth empowerment and emigration	Young people see no future in agriculture and are eager to emigrate.	Most young people think that agriculture is too hard and many wish to emigrate.	Most young people do not want to emigrate, despite hard working conditions, and wish to improve their livelihoods and living conditions within their community.	Most young people (both boys and girls) are satisfied with working conditions and do not want to emigrate.	Young people (both boys and girls) see their future in agriculture and are eager to continue and improve the activity of their parents.
Animal welfare	Animals suffer from hunger and thirst, stress and diseases all year long, and are slaughtered without avoiding unnecessary pain.	Animals suffer periodically/seasonally from hunger and thirst, stress or diseases, and are slaughtered without avoiding unnecessary pain or they are not free to express their natural behaviour.	Animals do not suffer from hunger or thirst, but suffer from stress, may be prone to diseases and can suffer from pain at slaughter or are not free to express their natural behaviour.	Animals do not suffer from hunger, thirst or diseases but can experience fear discomfort and stress, especially at slaughter.	Animals are free from stress, hunger, thirst, pain, or diseases, discomfort, are free to express their natural behaviour, and are slaughtered in a way to avoid unnecessary pain.

CIRCULAR AND SOLIDARITY ECONOMY

INDEX	0	1	2	3	4
Products and services marketed locally (or with fair trade)	No product/service is marketed locally/fairly (or not enough surplus produced), or no local market exist.	Local (or fair) markets exist but hardly any of the products/services are marketed locally.	Local (or fair) markets exist. Some products/services are marketed locally (or in fair trade system).	Most products/services are marketed locally (or in fair trade schemes).	All products and services are marketed locally (or in fair trade schemes).
Products and services marketed locally (or with fair trade)	No networks of producers for marketing agricultural production exist. No relationship with consumers. Intermediaries manage the whole marketing process.	Networks exist but do not work properly. Little relationship with consumers. Intermediaries manage most of the marketing process.	Networks exist and are operational, but don't include women. Direct relationship with consumers exists. Intermediaries manage part of the marketing process.	Networks exist and are operational, including women. Direct relationship with consumers exists. Intermediaries manage part of the marketing process.	Well established and operational networks exist with equal women participation. Strong and stable relationship with consumers. No intermediaries.
Local food systems	Community is totally dependent on the outside for purchasing food supply and agricultural inputs and for the marketing and processing of products.	The majority of food supply and agricultural inputs are purchased from outside and products are processed and marketed outside the local community. Very few goods and services are exchanged/sold between local producers.	Food supply and inputs are purchased from outside the community and/or products are processed locally. Some goods and services are exchanged/sold between local producers.	Equal shares of food supply and inputs are locally available and purchased from outside the community and products are processed locally. Exchanges/trade between producers are regular.	Community is almost completely self-sufficient for agricultural and food production. High level of exchange/trade of products and services between producers.

RESPONSIBLE GOVERNANCE

INDEX	0	1	2	3	4
Producers' empowerment	Producers do not have secured access to land or other natrual resources. They have no bargaining power and lack the means to improve their livelihoods and develop their skills.	Producers' rights are recognised but not always respected. They have small bargaining power and little means to improve their livelihoods and/or to develop their skills.	Producers' rights are recognised and respected for both men and women. They have small bargaining power but are not stimulated to improve their livelihoods and/or to develop their skills.	Producers' rights are recognised and respected for both men and women. They have the capacity and the means to improve their livelihoods and are sometimes stimulated to develop their skills.	Producers' rights are recognised and respected for both men and women. They are well organized and have the capacity and the means to improve their livelihoods and to develop their skills.
Producers' organizations and associations	Cooperation among producers is non-transparent, corrupted or non-existent. No existing organisation or they do not to distribute profits transparently and/or equally nor do they support producers.	One organisation of producers exists but its role is marginal and support to producers limited to market access.	One organisation of producers exists and provides support to producers for market access and other services (e.g. information, capacity development, incentives…), but women don't have access.	One organisation of producers exists and provides support to producers for market access and other services (e.g. information, capacity development, incentives…), but women don't have access.	More than one organisation exists. They provide market access and other services, with equal access to men and women.
Participation of producers in governance of land and natural resources	More than one organisation exists. They provide market access and other services, with equal access to men and women.	Producers participate in the governance of land and natural resources but their influence on decisions is limited. Gender equity is not always respected.	Mechanisms allowing producers to participate in the governance of land and natural resources exist but are not fully operational. Their influence on decisions is limited. Gender equity is not always respected.	Mechanisms allowing producers to participate in the governance of land and natural resources exist and are fully operational. They can influence decisions. Gender equity is not always respected.	Mechanisms allowing producers to participate in the governance of land and natural resources exist and are fully operational. Both women and men can influence decisions.

Appendix C: Ten criteria of performance of agroecology and their links to the Sustainable Development Goal (SDG) indicators (FAO, 2019)

Main dimensions	Core criteria of performance	SDG	SDG indicator
Governance	Secure land tenure	1, 2, 5	1.4.2 2.4.1 5.a.1
Economy	Productivity	2	2.3.1 2.4.1
	Income	1, 2, 10	1.1.1, 1.2.1 and 1.2.2 2.3.2 2.4.1 10.2.1
	Value added	10	10.1.1 10.2.1
Health & nutrition	Exposure to pesticides	3	3.9.1 3.9.2 3.9.3
	Dietary diversity	2	2.1.1 2.1.2 2.2.1 2.2.2 2.4.1
Society & culture	Women's empowerment	2, 5	2.4.1 5.a.1 5.a.2
	Youth employment opportunity	8	8.6.1
Environment	Agricultural biodiversity	2, 15	2.4.1 2.5.1
	Soil health	2, 15	2.4.1 15.3.1

Appendix D: Step 2 Core criteria of performance, Tool for Agroecology Performance Evaluation (TAPE) questionnaire (FAO, 2019)

Some sections of this step will ask information about expenditures, revenues or prices. Please specify the currency in which these values will be expressed:

LAND TENURE

Do you have any legal recognition of your land? *(for Pastoralists: is your mobility legally recognized?)*

Mark only one per category

	MEN	WOMEN
Yes		
No		

If yes, which type of Formal document do you have?

Mark only one per category

	MEN	WOMEN
Title deed		
Certificate of customary tenure		
Certificate of occupancy		
Registered will or registered certificate of hereditary acquisition		
Registered certificate of perpetual / long term lease		
Registered rental contract		
Secure mobility corridor		
Other		

Secure land tenure: perception and rights:

Mark YES or NO per category

	MEN	WOMEN
If yes, is your name listed as owner / use right holder on the recognized documents?		
Do you Perceive that your access to land is secure, regardless of whether this right is documented? (for Pastoralists: do you perceive that your mobility is secure?)		
Do you have the right to sell any of the parcels of the holding?		

Do you have the right to bequeath any of the parcels of the holding?		
Do you have the right to inheritland?		

AGRICULTURAL BIODIVERSITY, INCOME AND PRODUCTIVITY

This part of the survey can be conducted using a farm walk or a combination of farm walk and household survey

Output and earnings (*Take as reference the last year of productive activity)*

1. **Crops and trees**
    a. How many crop/tree species do you grow?
    b. List top 20 most important crops or trees. For each of them, specify:
        - Name of the crop species or type of crop.
        - Total production (kg).
        - Quantity sold (kg).
        - Price at the gate (currency/kg).
        - Quantity given for free (gift, present) (kg)
        - Land under production (ha).
        - Number of varieties/species produced.
2. **Crops products and forestry products**
    a. How many different crop or forestry products do you produce?
    b. List top 20 most important crop products or forestry products. For each of them, specify:
        - Name of the product
        - Unit of measure
        - Quantity produced
        - Sold
        - Price at the gate (currency/ kg)
        - Free
3. **Animals**
    a. How many different animal species do you raise?
    b. List top 20 most important animal types. For each of them, specify:
        - Name of the animal species.
        - Total number of animals of this species currently raised into the farm
        - Total number of animals of this species born during the last 12 months
        - Total number of animals of this species died of natural cases during the last 12 months

- Number of different breeds within these species.
- Number of animals sold.
- Price at the gate (currency/animal)
- Number of animals given for free (gift, present)

How do you feed your animals?

Mark only one:

- ❑ Mostly with feed
- ❑ Both with feed and on pasture
- ❑ Only on pasture

4. **Animal products**
   a. How many different animal products do you produce?
   b. List top 20 most important animal types. For each of them, specify:
      - Name of the animal product.
      - Unit of measure for this product:
        - ❑ Kg
        - ❑ L
        - ❑ Number of
        - ❑ Other (specify)
      - Total quantity produced.
      - Quantity sold.
      - Price at the gate (currency/unit of measure)
      - Quantity given for free (gift, present)
5. **Other activities/services related to agricultural production within the farm**
   a. How many other activities/services are you engaged in?
   b. List top 20 most important other activities/services. For each of them, specify:
      - Name of the activity/service produced or provided.
      - Total revenue.

Natural vegetation, trees and pollinators

Productive area covered by natural or diverse vegetation (natural pasture, grasslands, wildflower strips, stone or wood heaps, trees or hedgerows, natural ponds or wetlands, etc.). Consider communal land.

Mark only one

- ❑ Abundant: more than 25% of the system is covered with natural or diverse vegetation
- ❑ Significant: at least 20% of the system is covered with natural or diverse vegetation

- ❑ Small: less than 10% of the system is covered with natural or diverse vegetation
- ❑ Absent: area covered with natural or diverse vegetation is negligible

Beekeeping.

Mark only one

- ❑ Yes, bees are raised and are very abundant within the agroecosystem
- ❑ Yes, bees are raised within the agroecosystem
- ❑ No, bees are not raised but are widespread within the agroecosystem
- ❑ No, bees are not raised and are rare within the agroecosystem

Presence of pollinators and other beneficial animals within the agroecosystem?

Mark only one:

- ❑ Abundant
- ❑ Significant
- ❑ Little
- ❑ Absent

Expenditures for inputs

Take as reference the Last year of productive activity. Please express this value in the currency previously specified.

1. Total expenditures for Food for self- consumption:
2. Total expenditures for Seeds:
3. Total expenditures for fertilizers:
4. Total expenditures for feed:
5. Total expenditures for veterinary services:
6. Total expenditures for livestock purchases:
7. How many external workers did you engage in agricultural production of the system assessed?For each of them, specify:
    a. How many days did he/she work?
    b. How much did you pay him/her?

Energy, machinery and maintenance

1. Total expenditure for machinery/equipment and maintenance (*Please express this value in the currency previously specified):*
2. How many different pieces of machinery/equipment do you own?
3. List top 20 most important machineries/equipment. For each of them, specify:
    a. Name of the machinery/equipment.

b. Quantity owned.

c. Price ad purchase (per unit).

d. For how many years have you been using this machinery/equipment?

e. How many more years are you planning on using it/them (on average)?

4. Total expenditures for fuel:
5. Total expenditures for energy:
6. Total expenditures for transportation:

FINANCIAL INFORMATION

Take as reference the last year of productive activity. Please express this value in the currency previously specified

1. Total taxes paid:
2. Total subsidies received:
3. Total interest on loans paid:
4. Total cost for renting land:
5. The essential of household's revenue comes from *Mark only one:*
    - ❑ Crop production
    - ❑ Animal production
    - ❑ Other income-generating activities
    - ❑ Salary earned off farm
    - ❑ Remittances from a family member emigrated
    - ❑ Other:
6. What is the main intended destination of the agricultural production?
    - ❑ Sale
    - ❑ Mostly sale and a small part of self-consumption
    - ❑ Equally sale and self-consumption
    - ❑ Mostly self-consumption and a small part of sale
    - ❑ Self-consumption

Qualitative perception of earnings and expenditures

1. How do you compare your income compared to three years ago?
    - ❑ Much more income
    - ❑ More income
    - ❑ Same income

- ❑ Less income
- ❑ Much less income

2. How do you judge the stability of the output of your farm and the income derived from it?
   - ❑ Very stable and decreasing trend
   - ❑ Unstable wth notable fluctuations
   - ❑ Neutral sometimes up, sometimes down
   - ❑ Stable with minor fluctuations
   - ❑ Very stable and growing trend
3. How do you compare your living conditions with three years ago?
   - ❑ Much worse
   - ❑ Worse
   - ❑ Same
   - ❑ Better
   - ❑ Much better

Answer	Score
Market-oriented	100
Agropastoral production is equally for marketing and self-consumption	50
Self-consumption	0

EXPOSURE TO PESTICIDES

Consider the last 12 months as reference period.

1. How many different chemical pesticides have you used in the last 12 months of productive activity?
2. List top 10 chemical pesticides used. For each of them, specify:

When selecting the level of toxicity for each pesticide, please refer to the table below:

CATEGORIES		SIGNAL WORD	ORAL LD50 (mg/kg)	DERMAL LC50 (mg/kg)	INHALATION LD50 (mg/L)
I	Extremely/highly toxic	DANGER POISON / DANGER	0 to 50	0 to 200	0 to 0.2
II	Moderately toxic	WARNING	50 to 500	200 to 2000	0.2 to 2.0
III	Slightly toxic	CAUTION	500 to 5000	2000 to 20000	2.0 to 20
	Relatively non-toxic	CAUTION [optional]	5000+	20000+	20+

a. Name of the pesticide.
b. Level of toxicity.
c. Quantity of product used (*l* or *g*).
d. Amount of area in which the pesticide has been used (ha).
e. On which crop?
f. For treating which pest?

3. Total expenditure for chemical pesticides:
4. How many different organic pesticides have you used in the last 12 months of productive activity?
5. List top 10 organic pesticides used. For each of them, specify:
   a. Name of the organic pesticide.
   b. Source: self-produced or purchased?
   c. Quantity used (l or g).
   d. Amount of area in which the pesticide has been used (ha).
6. Total expenditure for organic pesticides:
7. Mitigation strategies when applying? *Select as many as necessary.*
   - ❑ Mask
   - ❑ Body protection (glasses, gloves, etc.)
   - ❑ Special protection for women and children
   - ❑ Visible signs of danger after spraying
   - ❑ Community is informed of the danger
   - ❑ Secure disposal of the empty containers after use
   - ❑ Other:
   - ❑ None of these

Ecological management of pests.

1. *Select the techniques systematically applied within the system assessed. Select as many as needed.*
   - ❑ Cultural control (more resistant varieties are chosen for production; plants and fruits presenting signs of disease are removed manually; crops are grown in crop rotation and intercropping schemes, etc.)
   - ❑ Plantation of natural repelling plants
   - ❑ Use of cover crops to increase biological interactions
   - ❑ Favor the reproduction of beneficial organisms for biological-control
   - ❑ Favor biodiversity and spatial diversity within the agroecosystem
   - ❑ Other:
   - ❑ None of these

2. Which type of pesticides are more important for your production? *Mark only one option*
    - ❑ Pesticides use is negligible (neither chemical nor organic) ecological management is more important.
    - ❑ Organic pesticides are more important.
    - ❑ Nor organic, nor chemical, no ecological management.
    - ❑ Chemical and organic pesticides have the same importance.
    - ❑ Chemical pesticides are more important.
3. Do you use antibiotics on your livestock?
    - ❑ I do not use antibiotics at all
    - ❑ For treatment of diseases only
    - ❑ For prevention of diseases
    - ❑ For both prevention of diseases and growth promotion
    - ❑ For growth promotion

YOUTH EMPLOYMENT AND EMIGRATION

1. How many young members (15-34 years) are there in the system assessed (including those emigrated and currently living outside it)? For each of them specify:
    a. Name (optional)
    b. Sex of the youngster
    c. Has this youngster already emigrated for lack of employment? If the answer to this last question was “no”, please specify:
2. What is the occupation of the youngster?
    - ❑ Working in the agricultural production within the system assessed
    - ❑ Both working in the agricultural production within the system and also employed outside the system
    - ❑ Employed outside the system assessed
    - ❑ Both working in the agricultural production within the system and also enrolled in formal education
    - ❑ Enrolled in formal education
    - ❑ Not working nor studying
    - ❑ Works in his/her own farm
4. This youngster would like to be a farmer in the future? Yes/No
5. What is the occupation of the youngster? Yes/No

Survey to be conducted only with the main woman in the household without the presence of a man in a safe environment.

1. Is the woman answering with the presence of a man? Yes / No

If yes: has the man refused to leave despite knowing that this? Yes / No

Education level

	MEN	**WOMEN**
Cannot read nor write		
Able to read and write		
Elementary		
High		
University		

Time burden

Leave the spot empty if a category is missing.

Number of hours spent working on **agricultural production** within the system assessed

	MEN	**WOMEN**
Number of hours spent working on **agricultural production** within the system assessed		
Number of hours spent working on **food preparation** and other **domestic works**		
Number of hours spent working on **other gainful activities** (outside agricultural production)		

Decision making

Do women make decisions on what to produce? Do women make decisions around what to do with the outputs produced (such as control over the income, and whether to consume at home)?

Mark only one per category

	MYSELF (Women)	**MY HUSBAND (Men)**	**BOTH OF US**	**SOMEONE ELSE**

Who is the owner of the **crops** and the **seeds**?				
When decision is taken about **crop production**, who normally takes these decisions?				
Who is the owner of the **animals**?				
When decision is taken about **animal production**, who normally takes these decisions?				
Who is the owner of the assets for other economic activities within the household?				
When decision is taken about other economic activities within the household, who normally takes these decisions?				
Who is the owner of **major household assets**? (house, machineries, etc.)?				
When decision is taken about **major household assets**, who normally takes these decisions?				
Who is the owner of **minor household assets**? (small tools, garden, etc.)?				
When decision is taken about **minor household assets**, who normally takes these decisions?				

Decision-making about revenue:

Mark only one per category

	Did not contribute or contribute to few decisions	**Contributed in some decisions**	**Contributed to most decisions**

How much did you contribute to the decisions about the use of the **revenue** generated through **crop production**?			
How much did you contribute to the decisions about the use of the **revenue** generated through **animal production**?			
How much did you contribute to the decisions about the use of the **revenue** generated through **other economic activities**?			

Perception about decision-making

Mark only one per category

	I think that I cannot take any decision	**Just little decisions**	**Some decisions**	**In great part / totally**
If you wanted, do you feel that you can take decisions about **crop production**?				
If you wanted, do you feel that you can take decisions about **animal husbandry**?				
If you wanted, do you feel that you can take decisions about **other economic activites**?				
If you wanted, do you feel that you can take decisions about **major household's expenditures**?				
If you wanted, do you feel that you can take decisions about **minor household's expenditures**?				

Do you have access to credit?

Mark only one per category

	MEN	WOMEN
Possible in official and secure channels (bank or similar)		
Possible in non-official channels		
Not possible. Access to credit is too hard or too risky		

Leadership

Men and women face different barriers to participation. Within the country/context, are both men and women within the household included and able to participate in the agroecology projects?

	Does this group exist in your community? YES/NO	**How often do you participate in activities and meetings organized by this group (if it exists in your community)?**			
		Never/almost never	Sometimes	Most of the time	Always
Women's associations and organizations					
Cooperatives for rural production					
Social movements					
Unions of rural workers					
Political groups linked to a party					
Religious groups					
Training organized for capacity development					
Others					

MINIMUM DIETARY DIVERSITY FOR WOMEN

This section should preferably be conducted with a woman aged 15-49 years old. If there are no family members with such requirements, the survey may continue to be conducted with the family member who was already being interviewed.

Select what you ate or drank in the last 24 hours. Please include all foods and drinks, any snacks or small meals, as well as any main meals. Remember to include all foods you may have eaten while preparing meals or preparing food for others.

Mark only one per category

Food groups:	**Yes, I ate it in the last 24 hours**	**No, I did not eat it in the last 24 hours**
Grains, white roots and tubers (bread, rice, pasta, flour, white potatoes, white yams, manioc / cassava / yucca, taro, etc)		
Pulses (beans, peas, fresh or dried seed, lentils or bean / pea products, including hummus, tofu and tempeh)		
Nuts and seeds (Tree nut, groundnut/peanut or certain seeds, or nut / seed “butters” or pastes)		
Dairy products (Milk, cheese, yoghurt or other milk products but not including butter, ice cream, cream or sour cream)		
Meat, poultry, fish (Beef, pork, lamb, goat, chicken, fish, seafood, animal organs)		
Eggs from poultry or any other bird		
Dark green leafy vegetables (any medium to-dark green leafy vegetables, including wild / foraged leaves)		
dark yellow or orange fruits and vegetables (mango, papaya, pumpkin, carrots, squash, orange sweet potatoes)		
Other vegetables (cucumber, eggplant, mushroom, onion, tomato, etc.)		
Other fruits (avocado, apple, pineapple, etc.)		

SOIL HEALTH

For the soil assessment, choose the surface of the productive area that most reflects the average status of its soil.

Mark every category with a score comprised between 1 and 5 following examples.

Indicators	Established value	Characteristics	Score (from 1 to 5)
Structure	**1**	Loose, powdery soil without visible aggregates	
	3	Few aggregates that break with little pressure	
	5	Well-formed aggregates – difficult to break	
Compaction	**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	
Soil depth	**1**	Exposed subsoil	
	3	Thin superficial soil	
	5	Superficial soil (> 10 cm)	
Status of residues	**1**	Slowly decomposing organic residues	
	3	Presence of last year's decomposing residues	
	5	Residues in various stages of decomposition, most residues well-decomposed	
Colour, odour and organic matter	**1**	Pale, chemical odour, and no presence of humus	
	3	Light brown, odourless, and some presence of humus	
	5	Dark brown, fresh odor, and abundant humus	
	1	Dry soil, does not hold water	

Water retention (moisture level after irrigation or rain)	**3**	Limited moisture level available for short time	
	5	Reasonable moisture level for a reasonable period of time	
Soil cover	**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	
Erosion	**1**	Severe erosion, presence of small gullies	
	3	Evident, but low erosion signs	
	5	No visible signs of erosion	
Presence of invertebrates	**1**	No signs of invertebrate presence or activity	
	3	A few earthworms and arthropods present	
	5	Abundant presence of invertebrate organisms	
Microbiological activity	**1**	Very little effervescence after application of water peroxide	
	3	Light to medium effervescence	
	5	Abundant effervescence	

Appendix E: 24-hour recall questionnaire for women

Interviewer:	Interview date *(Select date):*	Recall date:
Recall day: [Mon] [Tue] [Wed] [Thur] [Fri] [Sat] [Sun]	Recall Number: ❑ First recall ❑ Repeat recall	Sub-county name (Select sub-county): ❑ Emuhaya ❑ Hamisi ❑ Luanda ❑ Sabatia ❑ Vihiga
Sub-location name (Select Sub-location):	Name of the village:	Respondent's name:
Respondent's age in years:	Respondent sex **10.** Male **11.** Female	Respondent ID:
Around what time did you wake up yesterday? *(Select time):*	Was food intake usual yesterday? ❑ Yes ❑ No	Were you sick/ill yesterday? ❑ Yes ❑ No

Now I would like you to tell me all the foods and beverages that you consumed upon waking up yesterday, throughout the day (24hours), including any snacks you ate between meals. Please mention all food whether it was eaten at home or anywhere else.

Now I would like us to get into more details about the foods you have told me you ate yesterday during the day and night. *(The enumerator to ask the respondent to describe each food item consumed and record the description for each food item below)*

1. At what time of the day did you consume the food or beverage (*Select time)*:
2. Occasion the food or beverage was consumed?
    - ❑ Before breakfast
    - ❑ Break
    - ❑ Mid-Morning
    - ❑ Lunch
    - ❑ Afternoon
    - ❑ Dinner/Supper
    - ❑ Before sleep
    - ❑ During night
3. Where was the Bread prepared?

- ❑ Home
- ❑ Outside Home

4. Where did you consume the food and / or beverage?
    - ❑ Home
    - ❑ Outside Home
5. How was the food prepared?
    - ❑ Boiling
    - ❑ Stewing
    - ❑ Roasting
    - ❑ Shallow fried
    - ❑ Deep frying
    - ❑ Raw
    - ❑ Stir frying
    - ❑ Other:

Appendix F: Answers Agroecology Performance Evaluation (TAPE) questionnaire linking to their value in the dataset

Environmental and health dimension

Natural vegetation, beekeeping and pollinators

Answer	Value	Score
Natural vegetation		
Absent: area covered with natural or diverse vegetation is negligible.	1	0
Small: less than 10% of the system is covered with natural or diverse vegetation.	2	0.33
Significant: at least 20% of the system is covered with natural or diverse vegetation	3	0.66
Abundant: more than 25% of the system is covered with natural or diverse vegetation.	4	1
Beekeeping		
No, bees are not raised and are rare within the agroecosystem.	3	0
No, bees are not raised but are widespread within the agroecosystem.	2	0.5
Yes, bees are raised within the agroecosystem.	1	1
Presence of Pollinators		
Absent	4	0
Little	3	0.33
Significant	2	0.66
Abundant	1	1

Animals

Animal	Value
Cow/ Bull	0
Sheep	7
Goat	8

Pig	9
Rabbit	12
Chicken	13
Duck	14
Goose	15
Turkey	16
Other	771

Crops

Crops	Value
Maize	56
Bananas	486
Linseed	333
Nuts	234
Pulses	211
Artichokes	366
Almonds, with shell	221
Anise, badian, fennel, coriander	711
Apples	515
Canary seed	101
Dry beans	176
Fresh vegetables	463
Sorghum	83
Cassava	125
Soybeans	236
Groundnuts, with shell	242
Mangoes, mangosteens, guavas	571
Lemons and limes	497
Papayas	600
Avocados	572
Sugar cane	156
Millet	79
Sweet potatoes	122
Other	7777
Other roots and tubers	149
Dry cow peas	195
Pumpkins, squash and gourds	394
Green beans	414
Broad beans, horse beans, dry	181
Fresh fruit	619
Other	7771
Other	77771
Other	77772
Other	77773
Green maize	446
Oranges	490

Yams	137
Leguminous vegetables	420
Tea	667
Fruit	542
Carrots and turnips	426
Asparagus	367
Coconuts	249
Tomatoes	388
Green onions, shallots	402
Watermelons	567
Pineapples	574
Dry chillies and peppers	689
Other sugar crops	161
Dry onions	403
Potatoes	116
Green peas	417
Jute	780
Spinach	373
Tallowtree seed	305
Tropical fresh fruit	603
Green chillies and peppers	401
Melons	568
Other cereals	108
Plantains and others	489
Sunflower seed	267

Appendix G: Food ingredients open 24-hour recall divided across the food groups of the Minimum dietary diversity for women (MDD-W)

Ten food groups of MDD-W

Food groups	Food ingredients
Grains, White Roots, Tubers and Plantains	Maize, whole, flour, (unspecified
	Millet, bulrush, flour
	Rice
	Ugali
	Maize, grain, yellow variety, whole, dry
	Porridge
	White Chapati
	Wheat Flour (refined/fortified/sifted packaged)
	Flour, soya
	Sorghum, grain, white, flour
	Potato, Irish (English", "Arrowroot, flou
	Amaranth, whole grain
	Millet, finger, flour
	Green Maize, white, whole, grain, fresh
	Arrowroot
	Cassava, root, white
	Sorghum, Grain, Red, Flour
	Wheat, whole, flour
	Maize meal, sifted
	Boiled maize
	Cassava flour
	Githeri
Pulses	Bean, red, fresh
	Beans, kidney, dry
	Soybean, dry
	Garden peas, dry
	Flour, soya, full fat"
	Githeri
	Green grams
	Soya beans
	Cow peas
Nuts and Seeds	Nut, ground nut
	Bambara groundnuts, dried
Milk & Milk products	Milk, goat, fluid, whole
	Milk, cow, whole, fresh
	Butter (cow milk)
	Yoghurt, cow milk, whole, plain
	Milk cream, cow
	Milk, cow, skimmed, boiled

	Milk, cow, powder, whole
	Milk, camel, whole, fresh
	Milk, cow, whole, fermented (Lala - Industrial)
	Milk tea
Meat, Poultry & Fish	Tilapia
	Beef
	Pork, meat
	Nile perch, dry
	Fish, dried"
	Fish, (unspecified) smoked
	Beef, liver
	Dagaa fish (omena), dried
	Fish, fresh (unspecified)
	Chicken, raw
	Chicken (food item ID no food ingredients)
Eggs	Egg, chicken, whole
	Eggs (food item ID no food ingredients)
	Egg, duck whole
Dark Green Leafy Vegetables	Kale (sukuma wiki)
	Vine (African) spinach leaves
	Kale, Ethiopian (kanzera)
	Spinach, leaves
	Pumpkin, leaves
	Cowpea, leaves
	Mito (Rattle pod) leaves
	Black (African) nightshade, indigenous, leaves
	Jute mallow, leaves
	Spider plant, leaves
	Amaranth, leaves
	Cabbage, leaf head, white
	Beans leaves
	Managu
	Sukumawiki
	Kanzira
	Mrenda
	Kales (food item ID no food ingredients)
Other Vitamin A Fruits & Vegetables	Tomato, red, ripe
	Papaya, ripe
	Sweetpotato, orange, biofortified"
	Orange, pulp
	Carrot
	Passion fruit"
	Sweet potato, brown skin

	Pumpkin, flesh
	Pumpkin, flesh
	Sweet potatoes
	Orange (food item ID no food ingredients)
	Mango (food item ID no food ingredients)
Other Vegetables	Tomato, green
	Beet root
	Tomato, canned
	Vegetable salad
Other Fruits	Banana, plantain, green
	Avocado, ripe
	Pineapple
	Guava, pink-fleshed
	Tangerine, pulp
	Lemon peel

Other relevant food groups

Food groups	**Food ingredients**
Sweet foods	Sugar, white, granulated or lump
Sweet beverages	Drinking chocolate, powder
	Juice marrows
Other oils and fats	Vegetable cooking oil
	Cooking fat
	Cooking oil
	Margarine,80% fat
	Margarine,60% fat
	Shortening, commercial, vegetable fat
	Corn oil
	Liquid oil
	Salad oil
Condiments and seasonings	Onion, mature, red skinned
	Coriander Leaves, fresh
	Garlic
	Onion, spring
	Tea leaves
	Capsicum (sweet pepper), green
	Black tea
	Green Ginger (Mature), fresh
	Garam masala
	Saga
	Salt, iodized

Appendix H: Social dimension guideline survey 2023

The Womens empowerment score is calculated by the mean of the following domains: 'Productive Decision', 'Decision Making', 'Income Use', 'Leadership' and 'Time use'. 'Productive Decision' is defined by the mean of the following subdomains: Decisions about crops, animals & economic activities, Decisions for household expenditures. The value that is given in the dataset is given below and the score that is given to each of answer also for the domain 'Productive Decision'.

Productive Decision

Answer	Value	Score
Completely the man	1	0
Mostly the man	2	0.25
Both man and woman	3	0.5
Mostly the woman	4	0.75
Completely the woman	5	1
Someone else outside the family	6	0
Not applicable	7	NA

Decision Making

The 'Decision Making' score is calculated by the mean of the subdomains: 'Land tenure score', 'Credit score', 'Ownership score for Crops animals and assets' and 'Ownership score for household assets'. Possible answers were assigned with the following numbers: The total 'Decision Making' score is calculated by the mean of all subdomains.

Ownership

Answers	Value
Possible in official and secure channels (bank or similar)	1
Possible in non-official channels	2
Not possible. Access to credit is too hard or too risky	3

Credit

Women	Men	Score
Official channels	-	1
Non-official channels	**Not possible**	0.8
Non-official channels	**Non-official channels**	0.75
Non-official channels	**Official channels**	0.5
Not possible	**Not possible**	0.25
Not possible	**Non-official channels**	0.1
Not possible	**Official channels**	0
Non-official channels	**NA**	0.5

The domain 'Income Use' is calculated the same as 'Ownership' or 'Productive Decision'.

Leadership

Answer	Score
I do not participate in such organizations	1
I rarely participate in such meetings / organizations	2
I participate often but rarely speak in the meetings	3
I am an active member, sometimes speak in meetings	4
I often speak in meetings, participate in decision processes	5

The scores are then translated into a scale from 0-1 ((score-1) *0.25). Finally, the greater value of the two questions is taken as the Leadership score.

For the calculation of the 'Time Burden', the sum of the working hours per day is calculated. It is the sum of the hours spent on agricultural production food preparation and other domestic works and other gainful activities. We assume that the total worktime per day is maximum 18 hours. If the total worktime exceeds 18 hours, the single worktimes spent for agriculture, domestic and other work gets reduced by a factor, that it totals in 18 hours work per day. The first score is assigned the value of 1 if the sum of the working hours is lower than 10.5. Else it is 0. The second score defines if the other

gender works longer and is given a score of 1 if this is true and 0 if it’s not. The time use score is calculated by the average of the two scores.

The final Women's empowerment score is calculated by the mean of all the calculated domains. The means are then multiplied by 100. If there are no women on the farm the Women's empowerment score is NA.

Appendix I: Methodology for assessing market orientation and revenue evolution perceptions (Lucantoni et al., 2022)

Perception of the evolution of the revenue

Answer	Score
Sale	100
Mostly sale and a small part of self-consumption	75
Equally sale and self-consumption	50
Mostly self-consumption and a small part of sale	25
Self-consumption	0

Market orientation

Answer	Score
Market-oriented	100
Agropastoral production is equally for marketing and self-consumption	50
Self-consumption	0

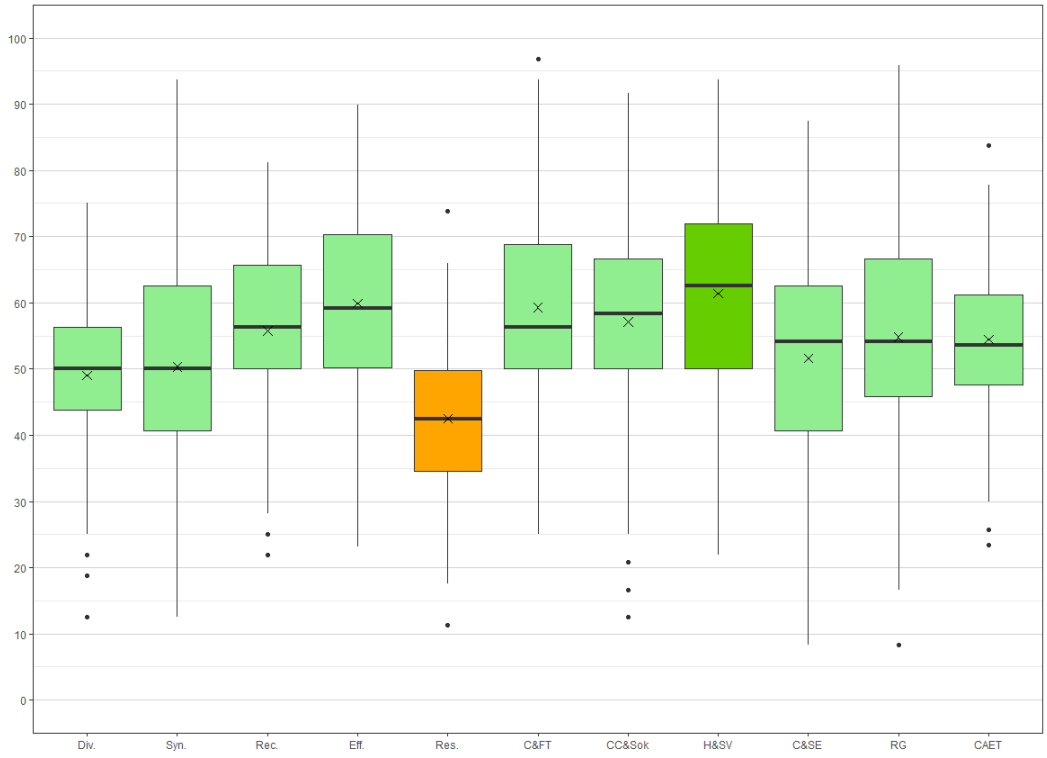
Appendix J: Detailed results of the gender and age composition across each category of characterization agroecological transition

	Men	Women	Young male	Young female	Children	Total members	% Family employed
CAET <30	0.6	0.5	0.6	0.7	2.1	4.5	45.6
CAET 30-40	0.8	0.7	1.0	1.2	2.2	5.9	40.4
CAET 40-50	0.9	1.0	0.8	1.1	2.5	6.3	52.2
CAET 50-60	0.8	1.0	0.9	1.1	2.3	6.1	49.4
CAET 60-70	1.1	1.1	1.0	1.5	2.3	7	48.5
CAET >70	1.1	0.8	1.7	1.2	1.9	6.7	52.8

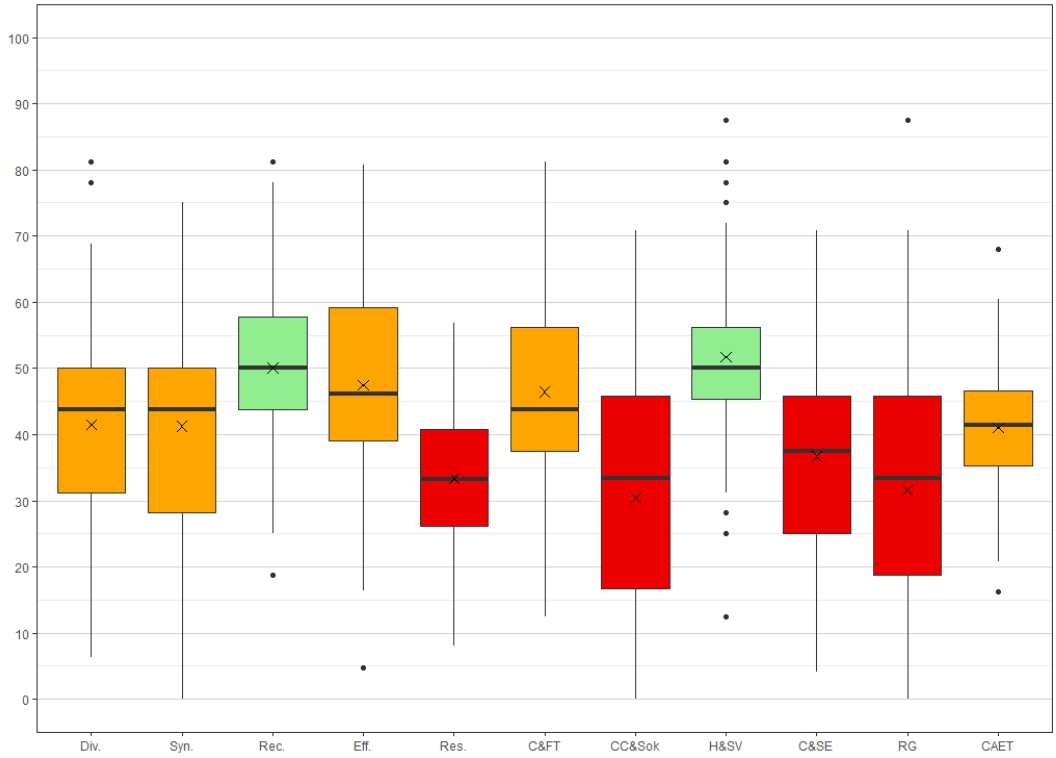
Appendix K: Detailed results of the average surface of land for farming, pasture, and natural vegetation across each category of characterization agroecological transition

	Farming	Pastures	Natural vegetation	Common Pasture Available	Total area (Ha)
CAET <30	0.14	0.01	0.01	0	0.16
CAET 30-40	0.22	0.01	0.02	0	0.25
CAET 40-50	0.3	0.02	0.02	0	0.34
CAET 50-60	0.45	0.08	0.04	0.01	0.58
CAET 60-70	0.91	0.16	0.13	0.25	1.45
CAET >70	0.72	0.14	0.01	0.05	0.92

Appendix L: Descriptive statistical analysis of characterization agroecological transition elements of the agroecological zone



Appendix M: Descriptive statistical analysis of characterization agroecological transition elements of the non-agroecological zone



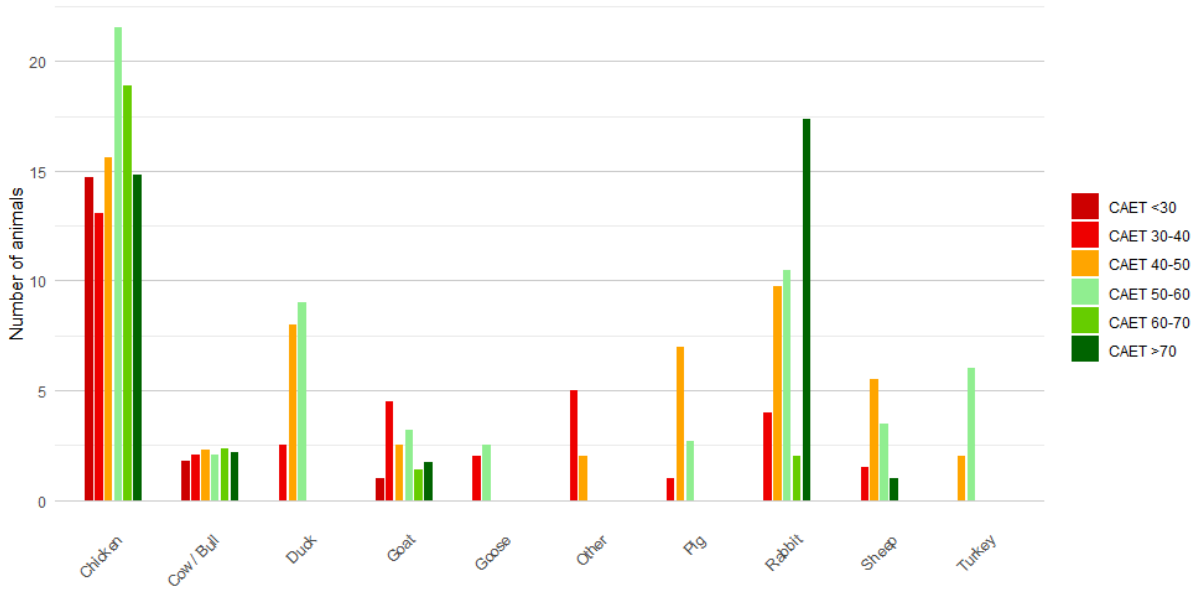
Appendix N: Detailed results of the households' gross value of the production per hectare, value added per hectare for characterization agroecological transition categories

	Gross value of the production/Ha (KES)	Standard Deviation Gross value of the production/Ha (KES)	Value added/ Ha (KES)	Standard Deviation Value added/ Ha (KES)
CAET <30	17500	881780	-8510	828800
CAET 30-40	221510	32947816	123550	32920162
CAET 40-50	389109	61811306	326317	61814030
CAET 50-60	452096	3707646	318000	3716680
CAET 60-70	370000	1711471	249717	1681750
CAET >70	191242	764115	180958	746530

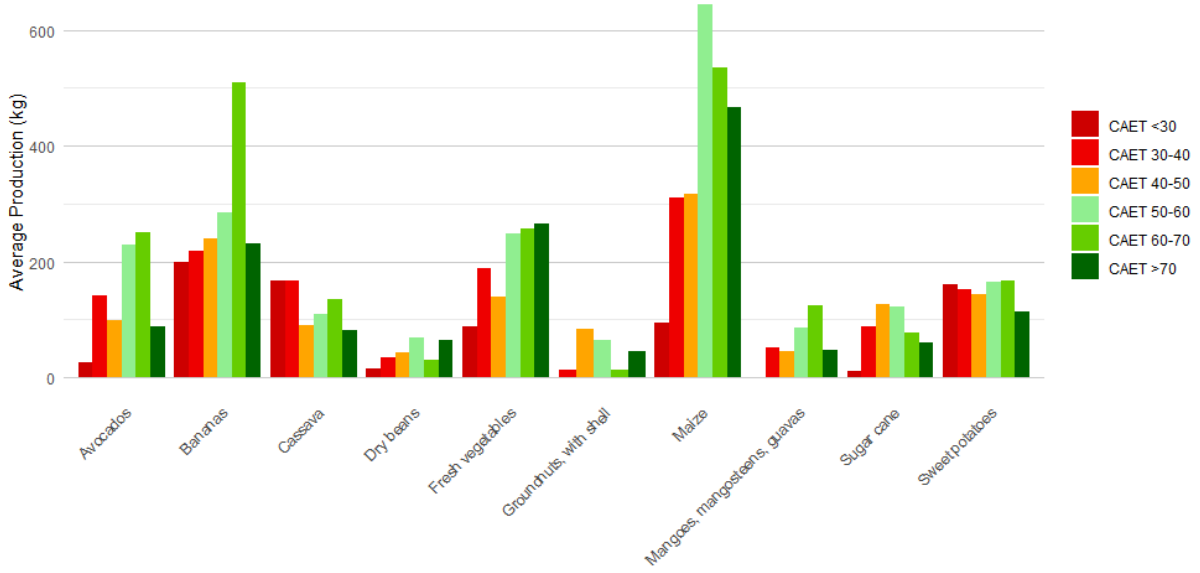
Appendix O: Detailed results of households' gross value of the production per person, value added per person and percentage of people earning less than $1.90 per day from the agropastoral activities per characterization agroecological transition categories

	Perception of the evolution of revenues (%)	Market orientation (%)	Net income / Person (KES)	Standard Deviation Net income/ Person (KES)
CAET <30	48	13	-838	56607
CAET 30-40	68	20	6371	657270
CAET 40-50	81	26	20103	3509067
CAET 50-60	74	26	24893	1189968
CAET 60-70	70	32	19702	125487
CAET >70	75	30	20865	43047

Appendix P: The average of ten most common animals for a household across all the characterization agroecological transition categories (Livestock per unit)



Appendix Q: The average of ten most common crop for a household across all the characterization agroecological transition categories (Kg)



Appendix R: The mean and standard deviation of the MDD-W for the listed-based and open 24-hour recall across the characterization agroecological transition categories

CAET Category	Mean MDD-W Listed-based 24-hour recall	Standard Deviation	Mean MDD-W open 24-hour recall	Standard Deviation
CAET <30	3.95	0.95	3.82	1.18
CAET 30-40	4.70	1.40	4.35	1.06
CAET 40-50	4.20	11.18	4.17	0.93
CAET 50-60	4.66	1.84	4.24	1.16
CAET 60-70	5.36	1.57	4.29	1.21
CAET >70	4.4	0.84	3.9	0.99

Appendix S: The mean and standard deviation of the MDD-W for the listed-based and open 24-hour recall for the agroecological zones and the non-agroecological zones

Zones	Mean MDD-W Listed-based 24-hour recall	Standard Deviation	Mean MDD-W open 24-hour recall	Standard Deviation
Agroecological Zones	4.22	9.31	4.13	1.11
Non-Agroecological Zones	4.81	1.62	4.24	1.03

Appendix T: The average land tenure score for women and men across the characterization agroecological transition categories

CAET Category	Land tenure Women	Land Tenure Men
CAET <30	18.2	39.5
CAET 30-40	20.3	37.5
CAET 40-50	31.9	50.0
CAET 50-60	31.4	45.6
CAET 60-70	30.0	50.0
CAET >70	45.0	55.0