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**Nature-Positive Agriculture for People and the Planet**

**A Qualitative Analysis from Kenya**

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## INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

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## Abstract

Agricultural intensification that prioritizes profits over people and the environment is increasingly recognized as harmful to people's wellbeing and the sustainability and resilience of smallholder farming systems. Nature-based solutions are part of nature-positive eco-agrifood systems and are critical for restoring ecosystems and preventing further biodiversity loss and environmental degradation during a climate crisis. To support more widespread adoption of nature-based solutions, it is important to understand dynamics within local communities where these solutions will be applied. This includes deeper understanding of environmental challenges, institutional and governance arrangements, current farming practices, gender relations, and perceptions of nature-based solutions. This study draws on qualitative data on these topics collected from smallholder farmers and key informants in three counties of Kenya. The discussion centers on the potential for nature-based practices to place agricultural production systems on a more sustainable path.

**Keywords:** Nature-based solutions, natural resources, gender

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## 1.0 Introduction

Thanks to investments in research, infrastructure, enabling policies, and market development associated with the Green Revolution, the world experienced remarkable growth in crop yields since the 1960s (Pingali 2014). However, the singular focus on boosting crop yields ignored issues regarding long-term sustainability of agrifood systems and negative externalities of food production at the landscape scale (TEEB 2018; FAO 2017). Unsustainable agricultural production has massive costs for people and the environment. In terms of its impact on the environment, unsustainable production systems contribute to land degradation, water scarcity and pollution, reduction of ecosystem services, deforestation, biodiversity loss, and greenhouse gas emissions (GHG) (FAO 2014; Ritchie and Roser 2020). In addition to these environmental impacts, unsustainable food systems also negatively affect people by failing to deliver healthy diets, safeguard human health, avoid hunger and malnutrition, support rural livelihoods, and address inequalities (FAO 2014). Shifting agricultural production to a more sustainable path requires accounting for these externalities and incentivizing practices and approaches that protect, restore, and maintain the resource base while providing opportunities for people to thrive.

Nature-positive food systems are recognized by the 2021 UN Food Systems Summit as a key pathway to transform agrifood systems toward resilience and equity (Hodson et al., 2021). As the name implies, nature positive solutions are not just about minimizing harm but actively enhancing natural systems, achieving a net-positive impact on ecosystems and biodiversity as well as livelihoods. Nature-based solutions (NbS) are a key component of this larger nature-positive vision, and were defined by UNEA 5 in Resolution UNEP/EA.5/Res.5 as “actions to protect, conserve, restore, sustainably use, and manage natural or modified terrestrial, freshwater, coastal, and marine ecosystems, which effectively and adaptively address social, economic, and environmental challenges, while simultaneously providing human wellbeing, ecosystem services, resilience, and biodiversity benefits.” Nature Positive is a societal goal to halt and reverse nature loss by 2030, and to achieve full nature recovery by 2050 (Nature Positive Initiative, 2023). Nature-positive agriculture is thus an aspirational goal that requires more widespread adoption of NbS to achieve it.

Scaling NbS requires producers, including smallholder producers in low-income countries, to consider how their operations affect the broader landscape and to adopt practices that minimize negative externalities. It also requires enabling policies and incentives to overcome barriers to adoption, such as investments in agricultural research and development (R&D), extension services, and financial innovations to support the transition to more sustainable food systems (Iseman and Miralles-Wilhelm 2021). Addressing gender and other inequalities in agrifood systems is also needed to ensure that those most affected by unsustainable farming practices can contribute to and benefit from NbS (Elias et al. 2021). Research shows that adoption of NbS

and sustainable farming practices more generally also have benefits for farmers in terms of crop yields, livestock productivity, and livelihoods, while also conserving resources and protecting the environment (Akanmu et al. 2023; Zeweld et al. 2020; Liu, 2020).

While the importance of transitioning to nature-positive food systems is recognized, there is limited evidence on the conditions driving acceptance and adoption of NbS. More research is needed to understand the relationship between environmental degradation, inequalities in access to resources, and behavior change leading to the adoption of nature-based solutions. More evidence is also needed on inclusive governance arrangements and institutional factors that support equitable scaling of solutions. Lastly, understanding the level of farmers' awareness of and their preferences for nature-based solutions is essential given that small farmers are often the most affected by the negative impacts of unsustainable farming and are key to driving the food system transition. This study analyzes qualitative data collected from smallholder farmers and key informants in three counties of Kenya. These data shed light on local environmental challenges (including availability and access to natural resources), institutional and governance arrangements, the environmental and social implications of current farming practices, gender dynamics and their influence on environmental and farming outcomes, and gendered perceptions of nature-based solutions. The discussion explores opportunities for nature-based practices to address local challenges and place agricultural production systems on a more sustainable path.

## 2.0 Conceptual framework

This paper draws on a conceptual framework that highlights key relationships and connections between elements of the complex nature-agriculture-human system drawing on the three main domains defined by the FAO (2014) and TEEB (2018) frameworks: 1) the natural system, 2) the human system, and 3) the agriculture system (Figure 1). These systems are supported by different types of capital including natural capital (e.g. natural resources), human capital (e.g. knowledge and skills), social capital (e.g. social networks and institutions), manufactured capital (e.g. material goods, technologies, and fixed assets), and financial capital (e.g. access to credit, savings, and assets) (Porritt, 2007).

The framework shows that agricultural systems depend on the natural system including natural capital (including soil, air, water, and biodiversity) and the ecosystem services they provide (e.g., soil retention, soil structure and fertilization, nutrient cycling, water provision and purification, pollination, and biological pest control) (Zhang et al. 2007). The ability of agricultural systems to deliver multiple goods and services (e.g., food, fiber, and fuel) in an environmentally and socially sustainable way depends on the quantity and quality of natural capital available to agriculture.

Key resources critical for the ability of agricultural systems to deliver these goods and services include land and soils, water, forests, and biodiversity. The ability of agriculture to produce crops

efficiently with high yields and high nutritional value depends in large part on the quality of land and soils that are available for agricultural production, especially in low-input production systems. Water is another essential input to agricultural production. In rainfed systems, as are common in Africa south of the Sahara, water scarcity is often perceived to be the most limiting factor to crop productivity (Rockström and Barron 2007). Access to water for production influences everything from crop choices, to yields to stability of food supply and resilience to climate change and shocks. Forests are also a key natural resource for communities, especially in lower and middle-income settings, because of the role they play in sustaining subsistence systems by providing a source of fodder for livestock, firewood, and income (Muthuri et al. 2023). Proximity to forests is highly correlated with increased livestock productivity and nutrient balance (Chavarria et al. 2018). Biodiversity also has a vital role in ensuring the functionality of ecosystems and the provision of services, such as pollination (Losey and Vaughn 2006).

The agricultural system also has implications for the natural system. Agriculture has a wide range of potentially negative impacts on natural resources, which—in turn—can adversely impact agricultural productivity in the future. Agriculture is a key source of environmental degradation and reduction in species diversity (MEA 2005). Globally, there has been an increase in the amount of land cleared of natural vegetation (Seppelt et al. 2014), in the intensification of management activities (Pimentel et al. 2005), and in the simplification of landscape structure, such as through an increase in broad-scale agricultural practices (Foley et al. 2005, Václavík et al. 2013). These changes have resulted in land use expansion and deforestation, land degradation, increasing GHG emissions, depletion and pollution of freshwater resources, and biodiversity loss.

Similarly, agricultural systems influence human systems by providing food, nutrition, and economic and social benefits, although not always without costs in terms of health or social inequality. There is a wide variety of farming systems across the globe that vary according to farm size (smallholder production vs. large scale production), input intensity (specifically, rainfed vs. irrigated), agroecological context (which determines what can be produced), country context, and institutional factors (e.g. governance), among other factors. Agricultural systems play a fundamental role in ensuring human wellbeing through the provision of essential goods that provide for the food, nutrition, energy, and development needs of the human population. In addition, agricultural systems provide a range of economic and social benefits from generating economic growth, particularly among low-income countries, to reduce poverty, to provide a foundation for sustaining cultural heritage and values.

Despite these positive benefits, current agricultural systems also have significant limitations and costs. For instance, the distribution of agricultural goods has not been even across countries, region, or people, given differences in economic and physical access to food, food utilization, and their stability over time (Barrett 2010). Unequal distribution of food (across and within countries) also leads to nutritional imbalances (e.g., underweight, obesity, and micronutrient deficiencies)

and rapidly developing countries may also experience the triple burden of malnutrition (hunger, undernutrition, and overnutrition) (IFPRI, 2017). Moreover, as agricultural production has intensified, there has been increasing homogeneity and a reduction of biodiversity in global food supply to the disadvantage of some local crops that are not only important for healthy diets and nutrition but also economic and social reasons (Khoury et al. 2014). There are also direct health risks posed by agricultural production, including from exposure to agrochemicals, such as pesticides (TEEB 2018) and from the increasing use of antibiotics in livestock and fish production which contributes to antimicrobial resistance (Van Boeckel et al., 2015).

While agriculture remains an important source of employment in many low-income countries with large agricultural sectors, agricultural systems can hinder the achievement of decent employment given the prevalence of child labor and temporary migrant workers with limited protections (ILO 2011). Moreover, the distribution of economic costs and benefits from agricultural production are uneven, with women and other marginalized groups less likely to access to the resources, technologies, and assets needed for maximizing agricultural production or to control income from their efforts (FAO 2023). Thus, given that the costs and benefits from agricultural production are distributed unequally, changes in farming systems through the introduction of nature-based solutions have different implications for people based on their gender, wealth status, age, ethnicity, and other intersectional identities.

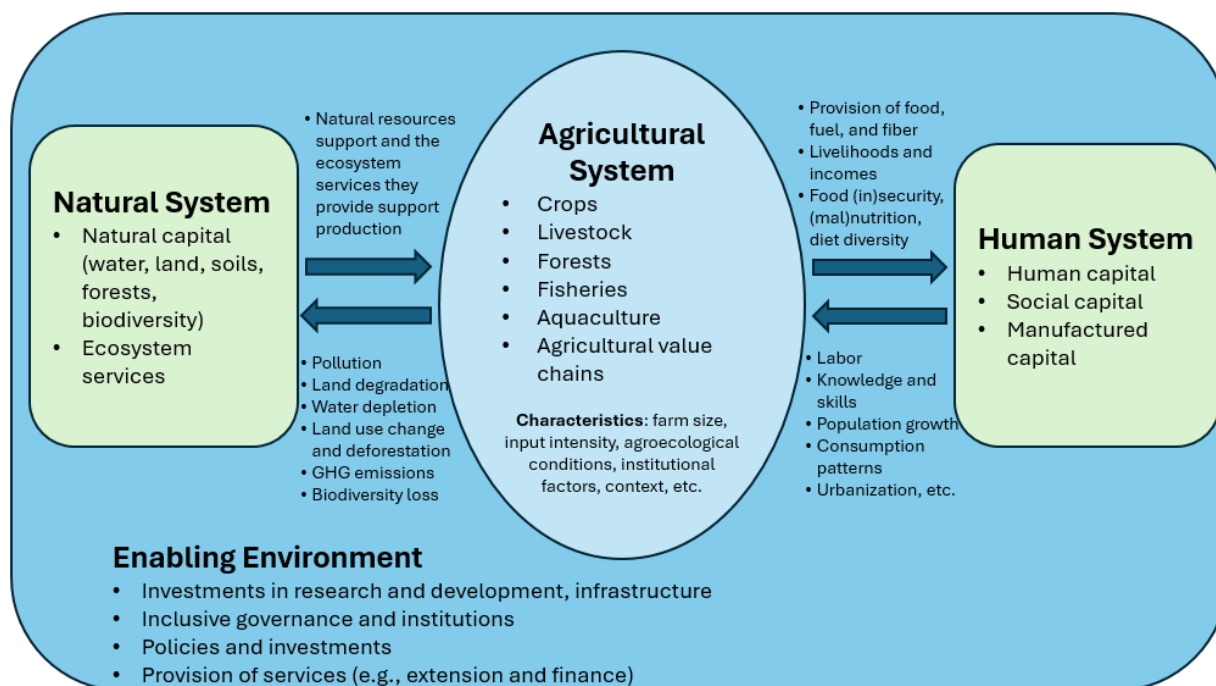
Human systems also drive change in agricultural systems in both positive and negative ways. Consumption patterns drive agricultural production both locally and globally. Dietary preferences and demand for foods influence food production choices and have serious implications for environmental outcomes, such as the level of GHG emissions from agriculture. Other drivers include population and economic growth, urbanization, and economic restructuring. Human capital is also an important driver of change in agricultural systems. For example, people provide their labor and apply their knowledge and skills to production. This knowledge is essential for farmers to adopt NbS that can sustain their livelihoods while also protecting the environment.

Social inequalities based on gender, age, wealth status, and other identities can also influence agricultural systems, including the adoption of NbS. Deeply rooted gender norms and stereotypes result in clear differences in how men and women access, use, and manage water resources (Bukachi et al. 2021). Women's involvement in decision-making around water resource management is limited by traditional gender roles and responsibilities (Coulter et al. 2019). In agriculture in Kenya, women account for between 42-65 percent of the labor force although they lack access to land, financial resources, and training (Nackoney 2022).

The enabling environment, including policies, institutional factors, and investments, shapes the linkages between natural, agricultural, and human systems within a given context. For instance, investments in agricultural R&D are essential to increase agricultural production sustainably and to address emerging challenges, such as climate change. Enabling policies, such as those that

expand land rights and increase tenure security, can also contribute to more widespread adoption of sustainable practices, such as nature-based solutions.

Based on the relationships illustrated in this conceptual framework, several entry points for increasing the sustainability of agriculture can be identified (FAO 2014). These include: 1) improving efficiency in the use of resources in agriculture, 2) direct action to conserve, protect, and enhance natural resources, 3) protecting and improving rural livelihoods, equity, and social wellbeing, 4) enhanced resilience of people, communities, and ecosystems, and 5) responsible and effective governance methods. Given differences in environmental challenges, farming systems, socioeconomic, and institutional contexts, the path toward more sustainable agriculture may look quite different in different countries and regions. Therefore, better understanding the local context can help identify solutions that provide the greatest benefits across environmental and social goals.



**Figure 1: Conceptual Framework**

Source: Authors, adapted from FAO (2014) and TEEB (2018)

### 3.0 Methodology

#### Data collection

We collected using focus group discussions (FGDs), key informant interviews (KIIs), community resource maps, seasonal calendars, and in-depth interviews (Table 1). Data collection took place in Kajiado, Kisumu and Vihiga Counties spanning 22 days in February and March 2023. The study focused on exploring the communities’ perspectives on the impacts of unsustainable agricultural production and resource management practices, perceptions about and uptake of nature-based solutions, understanding of incentives for and barriers to implementation of nature-positive alternatives, as well as the role of organizations in supporting adoption of nature-positive practices at the household and community levels. The authors used different data collection methods for triangulation (Vimont 2015) to improve and strengthen the credibility of the data. Multiple tools also provided different perspectives on the key themes of the study that generated substantively different meaningful patterns, and contextual interpretations in data analysis.

Table 1. Data Collection Methods

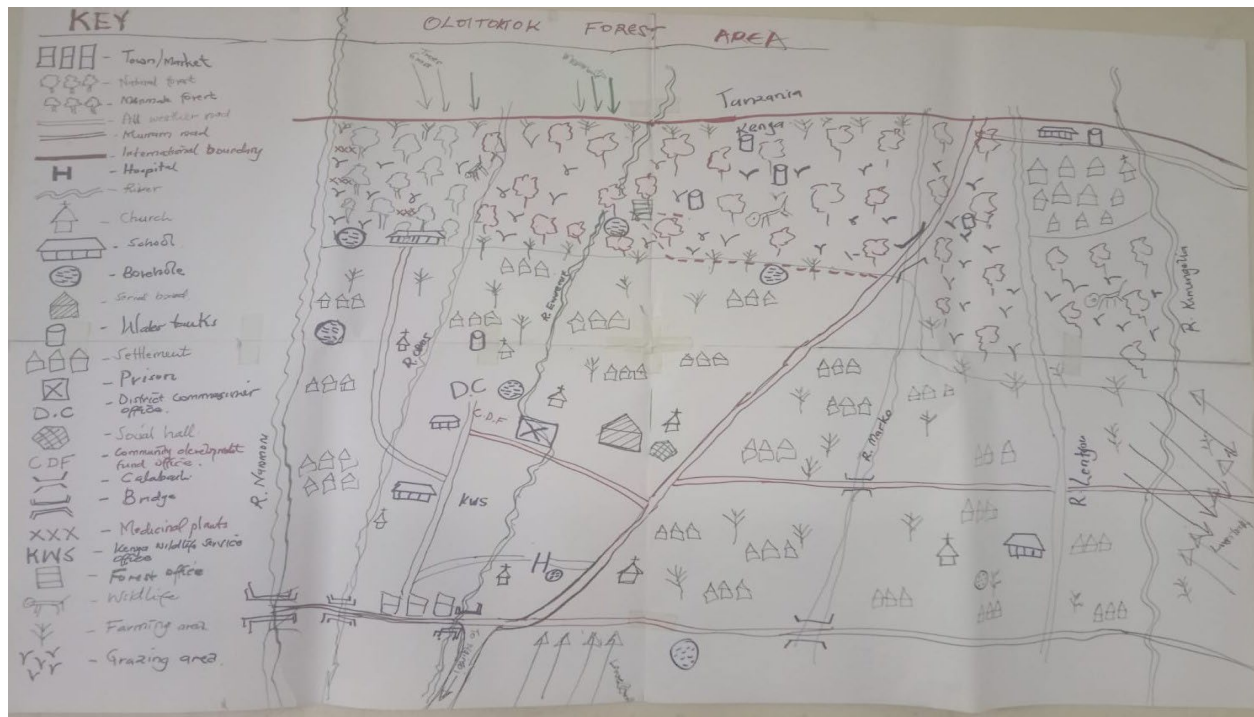
Method	Topics covered	Target participants
1. Key informant interviews	Local farming conditions, production, practices, and perception of NbS.	Extension workers, NGO project officers, cooperative leaders, local officials, community leaders, farmers.
2. Focus group discussion	Costs and benefits of current farming practices, nutrition and food security, intra-household decision-making, perceptions of, experience with, barriers to and incentives for adoption of NbS.	Groups of 8-10 men and women producers (groups of men and women separately).
3. Participatory resource mapping (FGDs)	Identify key natural resources and physical infrastructure, access to and governance of resources, movements, and places conflict in the community.	Groups of 4-5 men and women farmers of different ages and other resource-based livelihoods (e.g., fishers)
4. Seasonal calendar (FGDs)	Provide gender-based seasonality patterns of production and processing.	Groups of 4-5 men and women actively engaged in agriculture.

Source: Authors

The data collection instruments were designed by the study team and reviewed by experts for applicability and relevance in the study context. The tools were further subjected to two days of pretesting in Kiambu County of Kenya, upon which the tools were refined. The pretest process (Hurst et al. 2015) allowed for a contextual definition of themes and the study questions before collecting data. The tools were translated into the local language (Kiswahili) which ensured that the study's key concepts were made clear in the language of study communities.

The FGDs provided deeper and more nuanced insights into the communities' current farming practices, nutrition/diet diversity issues, perceptions of, experience with, and adoption of nature-based solutions, and the institutional landscape. In each county, eight FGDs were conducted with men and women of varying ages. The focus groups were disaggregated by sex: men-only and women-only groups made up of 8-12 participants. Youth were not recruited as separate groups (of young men and young women) but were integrated within the older men and older women focus groups. The group interviews were conducted in Kiswahili in Kajiado and Vihiga Counties while in Kisumu they were conducted in Dholuo, a local language. In Kajiado and Vihiga counties, some interviews were carried out in local languages (Kimaasai and Kimaragoli) and translated back to Kiswahili and then English.

Two participatory community resource mapping exercises were implemented in each county to understand the existing natural resources and infrastructure of the landscape. Participants were farmers/actors knowledgeable about their community resources. The groups were disaggregated by gender where there were men-only and women-only groups consisting of 4-5 members. The process involved developing a map that locates the community boundaries and identifies the nature and locations of natural resources and physical infrastructure therein (See sample resource map in Figure 1). Thus, through the community resource mapping exercise (Hossen 2016; Pearson et al. 2017), participants articulated their collective knowledge of their physical environment. Discussions with the participants on access to and management of community resources showed how the communities value their key resources, and how they are depended upon, used, and managed.



**Figure 2: Community Resource from Kajiado County.**

Gender-based seasonal calendars captured the seasonality patterns for agriculture-based livelihoods. The tool generated insights into farmers' knowledge and perception of the community's typical seasonal patterns (Chambers et al. 2021; Henningsen et al. 2020) such as weather conditions and timing, allowing for the visualization of patterns in livelihoods and in identifying the changes. Importantly, community calendars provided the perception of farmers on linkages between climate variability and agricultural activities at different points in the calendar year including changes in migration, spending, and agricultural-related workload between men and women and across seasons. In each county, two community seasonal calendars were conducted with men and women groups disaggregated by gender. The groups consisted of 4-5 participants.

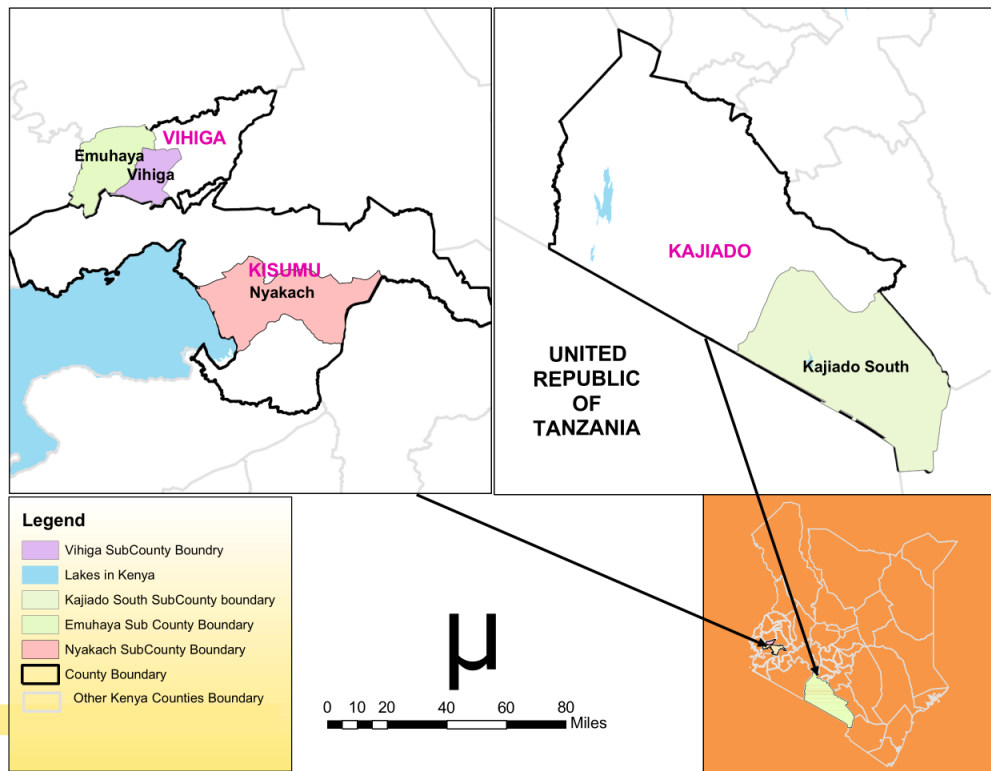
Key informant interviews targeted between five to seven participants in each county who were experienced and knowledgeable on communities' agricultural practices. These interviews focused on the externalities of current, unsustainable farming practices, promising nature-based solutions, nutrition and food security, shocks, and institutions. The researchers also attempted to understand the organizational efforts to promote NbS. The study ensured equal representation of men and women in the selected informants. Participants were drawn from community, county and national government and local non-state actors.

Semi-structured interviews with individual farmers were conducted to gain more insights into individual experiences and perceptions regarding unsustainable farming practices and NbS in Kisumu County. The interviews targeted both men and women. The IFPRI Institutional Review

Board and African Medical and Research Foundation (AMREF Health Africa) provided ethical approval to conduct the study.

## Sampling

The researchers purposively selected 19 communities from the three counties in Kenya that were part of the CGIAR Research Initiative on Nature-Positive Solutions (NATURE+): Kisumu and Vihiga counties in Western Kenya and Kajiado County in the Rift Valley region. In Kisumu, six communities were selected from villages in North Nyakach Ward in Nyakach Sub-County. In Vihiga data were collected in seven communities selected from West Bunyore and Central Maragoli Wards in Emuhaya and Vihiga Sub-Counties, respectively. In Kajiado County, data collection took place in Kimana Ward in Kajiado South Sub-County, where five communities engaged in mixed farming participated in the study. In addition, the selection of the communities was also based on the local agroecological conditions, existing farming practices and agricultural value chains.



**Figure 3: Data Collection Sites in Kenya (Source: Authors)**

Crop production and livestock rearing are the key prominent features of agriculture that support the socioeconomic lives of communities in the three counties. Although the sites may have distinct demographic and social foundations, the farming and livelihood practices experience similar challenges such as climate threats like drought (FAO 2015). The challenges reduce individual and collective livelihood opportunities and ability to act. Harnessing and incentivizing

existing agricultural resources (Bullock et al. 2019) can contribute to sustainable environmental resource use and agricultural production.

The study purposively sampled 288 (128 men and 142 women) participants in the 19 communities. A total of 199 (93 men and 106 women) farmers participated in the FGDs, 18 (12 men and six women) county and county-level experts participated as key informants and another 28 respondents (14 men and 14 women) participated in the resource maps in three counties. There were 27 respondents (13 men and 14 men) in the gender-based seasonal calendars, while in the semi-structured in-depth interviews, there were a total of 16 respondents (eight men and eight women) recruited in Kisumu County.

In total, six resource maps were completed (two in each county – one for men and another with women), along with six seasonal calendars (two in each county – one with men and another with women), 24 FGDs (eight in each county consisting of four men only and four women only groups), and 18 KIIs (seven, five, and six participants in Kajiado, Kisumu and Vihiga Counties). In the selection of study participants for the different interviews, the study deliberately targeted equal gender representation. The selection of participants was also based on convenience and respondent availability. The authors recruited different participants for the different data collection tools. All the study participants were reimbursed for the direct expenses where FGD participants received Kenyan shillings 500 and Key informants received Kenyan shillings 1,500. The sample size for the different methods was based on information power, hence, the guiding principle in sampling was data saturation (Malterud et al. 2016; Guest et al. 2006), which was achieved through sample specificity, quality-focused interviews, and the use of systematic analysis strategies.

Further, at the community level, the study team engaged the participants and shared detailed information about the study, highlighting its objectives, any anticipated risks and benefits for participants, confidentiality, anonymity, and voluntary participation. Any questions were addressed before the informed consent of the participants was sought. Only those potential participants who consented were recruited into the study and those who did not consent did not participate.

### Data processing and analysis

All group and individual interviews were conducted in the participant's language of choice and recorded using digital audio recorders upon receiving permission to record. The transcription of all the interviews began shortly after data collection and was completed in April 2023. The transcription was done by the study team that collected data in the respective counties and the transcripts were translated into English for analysis. Following a protocol developed by the study team, the transcription was done verbatim (word-for-word), and the transcripts were coded for purposes of identification. Personal information was removed from all transcripts.

The study authors adopted inductive and thematic approaches (Cooper et al. 2012) in the development of coding schemes to guide the data analysis process. In this manner, open coding was complemented by reading and re-reading through the transcripts to identify emerging themes (codes), patterns, and trends. A codebook was developed at this stage (Appendix 1). All transcripts and the codebook were imported into NVivo v. 14 (a qualitative data management and analysis tool) for formal coding and management. In NVivo, the coding process involved coding the data in the different transcripts to respective themes, and emerging thematic categories that had not been identified were added as they became available to modify the codebook.

Through substantial interpretations of the data (thick description), the findings were triangulated using various data sources (Gonzalez 2016). Verbatim quotations have been extracted and used in this study to exemplify the different and corresponding themes and project participants' voices.

### Study limitations

Community maps as participatory tools have provided contextually rich data on community resources and infrastructure. However, they do not provide cartographic precision, which could be used for community planning purposes. The resource maps only help to learn and identify key resources and how they are used and managed.

While we recognize that multiple intersectional identities, like age, marital status, and disability, influence resource use awareness, and adoption of nature-based solutions, our study focuses primarily on gender differences. Future research should explore differences based on age in exploring awareness and adoption of nature-based solutions; the study focuses primarily on gender differences. Future research should explore differences based on age, since it is a significant intersecting axis of identity that influences interactions with nature and participation in agriculture.

## 4.0 Results

### Resource profile of the study sites

To understand key resource features of the study communities, resource maps were drawn to document the availability of natural resources, infrastructure, and movements of people in relation to resource use. The maps detailed the placement of key resources such as water bodies, agricultural areas, forests, and wildlife as well as built structures such as settlements, markets, roads, schools, and clinics. They provided a basis for discussion on changes in resource use patterns, changes in resource quality and availability, how resources are managed and governed, and key drivers of change.

The results showed that forests are one of the most significant natural resources that the study communities rely on. Forests serve multiple roles in sustaining agricultural activities and livelihoods in the study areas. Communities rely on forests and trees as a source of fuel and income, with some households collecting wood to produce charcoal to sell in the market. In addition, forests provide grazing areas for livestock and, in some places, are a source of wild fruits and indigenous vegetables. However, the rise in deforestation rates has led to a decline in forest cover over the years. Forests in these communities are either private or public and are both planted and natural. Over time, exotic trees have replaced indigenous trees and natural forests. A male participant in Kajiado states that forests are helpful: "The forests are useful especially to women because they use them as fetching grounds for firewood. Some use the forests as sources of herbal medicine, while others use them to mine stones and murram [gravel]." In addition, forests are used as grazing areas for livestock and, in some areas, sources of wild fruits and indigenous vegetables.

Destruction of forests because of their use as a source of firewood and charcoal has led to prohibition of entry by the Kenya Forest Service (KFS) to users such as illegal loggers, men and women collecting firewood, and herders. The KFS works closely with community associations to aid in halting destruction and encourage forest cover conservation and restoration. According to a participant in Kajiado, KFS is working with those living near forests to ensure "that communities and nature co-exist." Community Forest Associations (CFAs) comprise of those who live around forests and rely on forests for food, pasture, and firewood. In Kisumu, village elders head forest management and work closely with the KFS. Besides forest management, the community takes part in forest restoration. KFS and CFAs have set up tree nurseries for this purpose. While women have traditionally been excluded from taking part in forest management leadership and restoration activities, gender roles are changing in some communities, such as Kajiado. One male respondent noted that "the Maasai community did not initially recognize the role of women, but with gradual changes and sensitization, women can work with the men in making the nursery beds."

Water is an essential resource for every aspect of life. In agricultural communities in Kenya, water is required for domestic purposes as well as for irrigation and livestock use. Water is also a source of income for water vendors. There are several sources of water available in the communities. Rainwater is the most common source (Boukaka 2024), and communities are highly dependent on rainwater for agriculture and domestic use. Due to the low uptake of water harvesting, the lack of rain significantly impacts agricultural production. A participant in Kajiado states, "We heavily rely on rainfall for farming in [our community] in such a way that if it fails to rain, we do not farm."

Rivers and springs are another vital source of water for the communities and are especially important during the dry seasons as the water is used for irrigation. However, this is not the case

in the study area in Kajiado County. A male participant in Kajiado noted that availability of water from the river is seasonal. [The river] does not have water during the dry season. Like now, it has dried because we have not had rain since December, but once it rains, the river will get water." The case is different in Kisumu County, where the geographical location means that rivers rarely dry up and members of the community rely on rivers as the primary source of water: "geographical structure of Kisumu County, 95% source is the streams, then 2% is water tanks, then tapped water takes 1%.....", according to a male respondent. For the few households that have piped water, rivers are still an essential fallback plan when taps run dry.

Many communities and households have private and public wells and boreholes. However, households in remote areas tend to have more limited access to this source of water and, in some cases, water is sold at five shillings per 20-litre jerrycan. The primary use of water from public boreholes and wells is for household chores and cooking. However, private boreholes and wells are not only used domestically but also for farming. In parts of Kajiado, where public boreholes have been sunk, "the water is pumped into tanks, and then it's supplied to people as tapped water."

Tap water is another vital water source, but the supply could be more assured, and the risk of finding taps dry is high. Water supply infrastructure is not well developed in rural areas in contrast to urban areas. In cases where tap water is available in the villages, water rationing is common with availability limited to a few days per week. Therefore, communities have always been ready with a different water source. A male participant in Kisumu emphasizes the importance of obtaining water from the river as it is "readily available as compared to tap water. In this area, tap water comes from the Sondu Miriu dam. In Kajiado, negotiations occur between communities living in Kenya and Tanzania before laying pipes into people's homesteads.

Land is a significant resource in all study sites. The land used in crops and livestock production can be owned or leased. The issue of land ownership remains a 'gender issue,' according to a female respondent in Kisumu County. This is emphasized by a male participant in Kajiado stating that finding women who own land is difficult. Despite this challenge of land ownership, many smallholder farmers farm on leased land. Farmers working on leased lands stated that they either own a small piece of land or none. Apart from crops cultivation, the land is particularly important for livestock production. This is in terms of fodder production and pastures. However, farmers who use their land as pastures have big farms where they can leave land fallow to gain fertility. Farmers with small pieces of land or none grow fodder crops such as Napier grass, hay, desmodium, lucerne and boma Rhodes grass. Those unable to grow fodder crops depend on forests as grazing areas.

Men and women have distinct roles when it comes to utilizing, managing, and governing natural resources. Fetching firewood is reserved for women and girls, whether for domestic use or sale. Men are involved in planting and pruning trees from which women obtain firewood. A male

participant in Vihiga emphasizes that men's role is "to cut down trees and chop them into firewood, women then carry them home."

Women and young girls are also responsible for fetching water. A female participant in Kisumu noted, "Women use water most frequently, and they are also the ones who go get it because they are responsible for many household tasks like bathing children, cooking, and washing." Men may help with the chore if it involves technology in some way, such as bringing home water on a motorbike. In Kajiado, men head negotiations on acquiring water from neighboring Tanzania. Finally, in instances where there is piped water, men are active in laying water pipes and repairing broken pipes.

Across the three counties, committees are formed to help manage natural resources such as water and forests. In Kisumu, the associations help "control sand harvesting and farming practices along the river." In Kajiado, the association monitors water usage while leading the restoration of forests and building infrastructure such as pumps and fences around the water resources. The Kenya Forest Service (KFS) works closely with community-formed Community Forest Associations (CFAs) in forest management. The association comprises farmers, loggers, and the community living in or around forests, which help manage and restore forest cover.

Quotas and other measures have been effective at increasing women's representation in committees governing natural resources. However, in some cases, women tend to lack decision-making authority. A woman in Vihiga mentions that "the two-third gender rule is adhered to." The two-third gender rule in Kenya states that, not more than two-thirds of members of elective public bodies shall be of the same gender (Government of Kenya, 2010). However, a woman in Kajiado noted that, "Most of the leadership of the water committees are men." A male participant in Kajiado explains that despite the Maasai not recognizing women's role in leadership in the past, women are more empowered now and "there are some CFA groups made of only women, and I know of three."

### Current farming system

The qualitative data shed light on the current farming systems and practices present in the study sites. Crop farming is more common in Vihiga and Kisumu counties while Kajiado is dominated by livestock keeping. Among the crops grown, maize is the dominant crop across the three counties, being the staple food in Kenya. According to a man respondent in Kisumu County, "The kind of farming done here most of it is for our consumption, a tiny portion is for commercial use, and the kind of crops planted are sorghum, maize, beans, and groundnuts." A male participant in Vihiga County reiterates this, explaining that "We largely rely on maize because it serves as both food and cow feed." Other crops grown in the three counties are beans, green grams, potatoes, cassava, sorghum, millet, sweet potatoes, and vegetables. Spinach, cabbages, tomatoes, onions, cowpea leaves, and kale are some types of vegetables grown in the three counties. In addition, indigenous vegetables, including African nightshade, slender leaves, spider plants, amaranth, jute

mallow, and pumpkin leaves, are grown in the western counties of Kisumu and Vihiga. Fruit trees are also common among the three counties as they are crucial in improving dietary diversity. Common fruits grown in the counties are mangoes, oranges, avocados, pawpaw, bananas, plums, and lemons.

While both men and women actively engage in crop production, they have distinct roles in production that vary by crop type. Men grow beans, millet, and other crops that fetch higher prices in the market. A male participant in Kajiado County explains, "A sack of beans goes for about twelve thousand shillings, so as a man, you cannot accept losing such an amount of money." Women plant maize when destined for household consumption or lower-value market sales. Women also grow vegetables for domestic consumption and, sometimes, for sale at the local markets.

Women play a crucial role in planting, weeding, and harvesting, while men are involved in land preparation, as this is perceived to be a challenging task that requires a man's strength. A male participant from Vihiga County explains that "the women will do the planting and weeding, and later harvesting. Women are the ones that generally participate in these farming activities." Another Kisumu County man mentions this is "because they [women] can bend a lot more."

Results showed that women are not the sole decision-makers regarding the planting of crops. In some instances, no farming activity can proceed without the "green light" from the [male] head of the household. According to a woman in Kajiado County, when the husband declines a request on how to proceed with planting, the wife accepts this decision to avoid household disagreements. However, women tend to have more decision-making power regarding the vegetable garden designated for household consumption.

Livestock farming is widespread in the three counties, with cattle, sheep, goats, and poultry dominating. Rabbits, pigs, and donkeys are the other types of livestock reared. A man in Kajiado County, where human-wildlife conflict is common, adds, "There are also other animals we keep for security; we keep dogs for protection at night, and we keep cats to chase away rats and snakes. Dogs protect us at night because wild animals come to human settlements at night and kill our goats, sheep, and cows." Animals are kept for both subsistence and commercial purposes. While livestock is an essential source of nutrition at the household level, they also function as a source of income. A man in Kajiado County explains, "We, therefore, keep animals because they are profitable and have a ready market. We do not have any other job that is easier than keeping livestock." In addition, livestock is kept for security and can be sold in case of emergencies to meet household needs. A women participant in Kisumu County states, "Most of the animals we keep as investments are cows and goats. We keep them as a bank because a child may be sent home from school because of school fees." A man in Kajiado County supports this: "it is crucial to have animals because you never know when a financial emergency, for example paying for school,

can arise. If you keep livestock, you can always sell one of your animals to receive the money you need. Therefore, having animals benefits us."

While fish farming is present in Kisumu and Vihiga Counties, it is not prominent due to the need for training and market access; fish from natural bodies such as the lake are deemed to be of better quality compared to those reared in fishponds. Using contaminated (e.g., treated mosquito nets) materials has negatively affected the quality of fish bred in fishponds. A man in Kisumu County states, "The fishing practices are not good because they use nets that are not recommended and some chemicals that kill fish in the water." However, the government has supported fish farmers through the Kenya Climate Smart Agriculture Program by providing dam liners, fingerlings, and good fishing practices. All these are done through subsidies to ensure fish farmers can afford them. An interviewee in Vihiga states, "They get a lot of training. They used to get a lot of subsidies too. The problem is with the feeds. The feeds were subsidized at some point and sometimes distributed for free." He adds that "All those people who had established those ponds, and we're carrying out fish production, received the subsidies."

Men own and control livestock; livestock farming is considered men's work. Although most animals are perceived to be the property of men, there are some gendered patterns of livestock ownership depending on the animal type. Men tend to own cattle, sheep, and goats, while women can only hold poultry. It is explained by a male participant in Kajiado that "In [traditionally pastoral] Maasai families, husbands are the ones owning livestock..." Despite limited livestock ownership, women play a significant role in caring for livestock. They are involved in feeding the animals and milking the cows. A man participant in Kajiado County explains that the woman in the household is responsible for milking the cows and cleaning the cowshed, and "the man comes in only during the slaughtering and selling of cattle." Cattle herding, however, is dominated by teenage boys. On poultry farming, women participants in Kajiado and Kisumu concur that chicken rearing and decision-making on selling chicken and eggs belong to women. According to a female respondent in Kisumu County income is then "used to purchase household commodities, seeds, and saving in the merry-go-round groups." In polygamous families in Kisumu County, it is more common for women to also own smaller ruminants compared to monogamous families, and there is a clear division of animals between the wives. The wives still often care for the husband's animals and their own.

### Changes in resource utilization, quality, and availability

Participants discussed changes in the quality, availability, and uses of resources on the study sites and the reasons for them. Respondents considered climate change, illegal logging, and clearing of forested areas for agriculture as key drivers of deforestation over time. Agricultural activities were viewed as negatively affecting natural resources including forests and water quality. At the same time, the declining availability and quality of water and soil negatively affects agricultural productivity.

One concerning trend in the study areas is the clearing of forest cover for agricultural production. While maintaining agricultural production and ensuring food security are important priorities, there are serious environmental consequences of forest clearing including biodiversity loss. A farmer in Kajiado County discussed the risk that agriculture poses to the environment due to the continuous deforestation with little or no effort to plant more trees. This is supported by a woman farmer in Kisumu County who states that there is need to strike a balance between agricultural production and environmental consciousness as loss of biodiversity affects agriculture production. Farmers perceived the link between deforestation and climate change, noting that cutting down trees for agricultural activities affects agricultural production due to the resulting change in weather patterns.

In addition, reliance on firewood and charcoal makes governing forest resources more challenging. Despite the government's strict ban on logging to curb charcoal burning and collection of firewood in government forests, communities continue to carry out these activities since charcoal and firewood remain the main source of energy in most homes and provides income for community members who sell them. Dealing with unemployment issues will reduce the challenge of governing and safeguarding forests as "the unemployed young men who cut down trees and burn charcoal to sell..." will have another source of income reducing pressure on forests.

There is also a general feeling across the study areas that water quality has declined over time, and that poor water management has led to the spread of waterborne diseases, such as cholera. Respondents perceived that bathing and washing clothing contributed to the deterioration in water quality. One participant in Kisumu County noted that during the dry season, "everybody uses the river to wash clothes, and this dirt stays in the river.... mostly women carry all the dirt from their homes as dirty clothes then soak them in the river." In addition, the change in water quality is attributed to the over-use of agricultural chemicals on farms, such as pesticides, herbicides, and fertilizers, which run off into rivers through soil erosion. In some instances, "the pesticides are being mixed at the water source, the same water source...where the animals are drinking their water...." The water, therefore, becomes unfit for human and livestock consumption. Water from rivers is not trusted to be safe, and communities have resorted to treating the water using water guards and boiling to kill harmful organisms. Community Health Volunteers (CHV) have become instrumental in educating community members on how to treat water to avoid contracting waterborne diseases, such as cholera and bilharzia. Agriculture not only contributes to resource degradation, but the declining availability and quality of natural resources also affects agricultural production. The fact that water from some rivers is only available during certain seasons (whereas previously it was permanently available) has affected agriculture during dry seasons. A female participant in Kajiado stated, "For the last ten years, people have used irrigation with river water, but that has been difficult of late. Many rivers have dried up, and the rain is not consistent. This phenomenon has affected agricultural activities."

Declining water availability also affects the time burden of women and girls, given that they are primarily responsible for collecting water for domestic use and irrigation of kitchen vegetable gardens. Climate variability and lack of storage facilities have exacerbated the challenge of water shortage.

Unsustainable agricultural practices also contribute to declining soil fertility. Some farmers perceive the causes of this to include monocropping, i.e., planting the same crop on the same piece of land for many years. Others point to challenges related to soil salinity, inappropriate application of fertilizers, poor quality of seeds, and lack of adequate water. Some farmers also considered that, "the quality of the soil available has reduced because we use a lot of chemicals and fertilizers." Declining soil fertility also negatively affects agricultural production by contributing to a decline in crop productivity. Some farmers see increased use of fertilizer to restore soil fertility. However, the rising cost of inorganic fertilizers makes this strategy unaffordable for many smallholder producers. As a result, most smallholder farmers are switching to organic farming and manure applications to improve soil health.

The problem of soil erosion was also widely discussed in all three counties. Soil erosion negatively affects production as topsoil, which is rich in nutrients, is carried away during the heavy rainy season. In Kajiado, farmers blame flowing water, wind, and overstocking of livestock as the leading causes of soil erosion. The lack of trees and terraces and unsustainable sand harvesting are also considered contributing factors. This challenge particularly affects those cultivating in steeply sloped areas. Lack of training on building gabions and terraces has left many farmers vulnerable to soil erosion.

For the restoration of soil, soil testing is the first step to restoring the fertility of the soils as it gives the state of soils and nutrients available and missing. Therefore, "our major issue is we are not doing soil testing. So, we do not know what is lacking in that soil." However, this activity comes at an extra cost for the farmers. According to an informant in Kisumu, "It requires one to pay 800 shillings per acre, which most farmers cannot afford." There needs to be awareness of soil testing as the starting point to restore soil fertility. Diammonium phosphate (DAP) has been discouraged due to soil acidification. Still, farmers do not know whether to stop using fertilizer because they do not know the soil's acidity level. Even if farmers knew which fertilizers to use on their farms given the needs of their soils, fertilizer availability is a challenge. DAP is sometimes the only fertilizer available in local fertilizer shops.

## Food security and nutrition

Despite the negative impact of agricultural production on the environment, smallholder production is essential to ensure food security, healthy diets, and adequate nutrition. Across the three counties, local production systems produce varied foods, ensuring that communities have access to diverse sources of food needed to have diverse diets. However, maize remains the most

common food, particularly *ugali* (ground maize meal) followed by *githeri* (a mixture of maize and beans boiled together). A man in Kajiado explains that maize meal is common because farmers plant maize for both consumption and sale, if the harvest is big enough. *Ugali* is typically eaten together with proteins, such as beef, mutton, eggs, chicken, milk, or fish. In addition, a cooked vegetable stew made of spinach, kale, jute mallow, amaranth, pumpkin leaves, African spider plant, slender leaves, Africa nightshade, or other vegetables may be consumed with *ugali*. Production systems in the study areas also provide important sources of nutritious diets including fruits (mangoes, oranges, bananas, passion fruits, pawpaw, avocados, guavas, and watermelon), legumes (beans, cowpeas, green peas), and tubers (Irish potatoes, sweet potatoes, arrowroots). To meet dietary requirements, households tend to purchase food from the market. A participant in Kajiado explains that foods that are not available or planted on the farm must be purchased at the market or at times bartered. "We do barter trade in the market since we are farmers. We can exchange beans for fruits. But right now, you will have to sell your farm's produce and get money to buy what you need from the market. Barter trade also occurs when a farmer has a surplus and wants to exchange for foods that they do not produce, such as exchanging beans for rice or maize flour. However, most of the vegetables consumed at home are produced on the farm.

Participants had different perceptions of the most important sources of good nutrition. However, the common view among all participants is that having access to diverse types of foods helps to reduce malnutrition. According to a man in Kajiado, to ensure diet diversity, "You can cook the rice with beans or cook the wheat flour mixed with cabbage and Irish potatoes, and you can supplement the diet with fruits from the farm." Sometimes the perceptions and preferences do not matter as the households eat what is available at a given time of the year. The data show that *ugali* is the main source of carbohydrates for many households. Households strive to accompany *ugali* with other foods such as beans, eggs, beef, chicken, and vegetables to have a balanced diet. However, access to these foods depends on household income and seasons (rainy or dry seasons). According to female respondent in Kisumu County, "during the rainy season, we have three meals daily; we only have two meals daily during the dry season; breakfast and dinner." Apart from maize, *ugali* can also be made from cassava, millet, and sorghum. A substitute for *ugali* is sweet potato, yams, or arrowroots. Fruits are an important source of minerals, and most households ensure that they have fruits though not as frequently as the other sources of food.

Respondents blamed the lack of proper diet diversity on a lack of information on different foods and their importance in providing well-balanced diets. According to a woman in Vihiga County, it is important for communities to sensitize that *ugali* should be accompanied by vegetables and proteins, but not potatoes. A man in Kajiado explains that "women with infants are the ones who get to be educated on nutrition whenever they visit the clinic; they get training on how to feed

the children a full balanced diet, which contains protein, vitamins, and carbohydrates.” Lack of information puts children’s nutrition at risk as parents do not know whether the food, they feed the children is well-balanced or not. In Kisumu, Community Health Volunteers (CHVs) have become an important source of information as they move door to door sensitizing communities about malnutrition.

Organizations such as World Vision and Better Living have been educating communities on what types of foods need to be consumed to attain healthy living. In addition, the government has included studies on nutrition to help children understand from an early age. The government also partners with radio stations to educate on the issue of malnutrition. But our findings show that most of the information on nutrition is accessible to those who visit hospitals, where nutritionists and dietitians advise patients.

### Nature-positive practices

The study shows that communities are slowly adopting nature-based solutions to combat the decline in agricultural productivity over the years. Adoption of NbS is heavily dependent on the knowledge and skills that farmers have and the practices that communities and individuals are aware of and perceive to be beneficial. In the study, we found that communities are adopting NbS for the transformation of ecoagrifood systems through restoring soil fertility and management of natural resources. Specific practices are crop rotation, intercropping, organic farming, composting, and digging terraces (as soil conservation measures to prevent soil erosion). Planting trees was also observed in the study as a soil conservation measure and a reforestation method. Critical to the goal of boosting agricultural yields and income is soil fertility restoration and management of natural resources, such as forests and water catchment areas. Participants in the study communities identified several practices they perceived would be beneficial for conserving the natural resource base to support and sustain agricultural production.

Crop rotation was viewed as an essential practice for sustaining agricultural production as it helps improve soil health and enhance biodiversity on the farm. The study results show that farmers know the importance of crop rotation to soil health and biodiversity. A woman participant from Kisumu states, "Crop rotation is an effective way to protect the environment. For example, I could plant maize one year and beans the next so that when the bean leaves fall, the farm will be more fertile." This practice is reiterated by a man in Kisumu who explains, "We should do crop rotation because monocropping destroys the fertility of the soil, which is why it is also advisable to plant a variety of crops like legume crops to help retain soil from erosion."

However, crop rotation has been on the decline, according to a key informant in Vihiga County. He explains: "we used to have crop rotations but no longer have them. I am not sure what caused it, but I can attest that the increased population caused a reduction in farm sizes."

Alternatively, many farmers use intercropping on small tracts of land. However, there are mixed views on the effects of intercropping on individual crop production. A woman in Kisumu believes that monocropping wastes space and prefers to intercrop maize, beans, and green grams. Another woman in Kisumu explains the importance of intercropping as it helps control the growth of the parasitic weed striga, "which destroys cereal crops, so we would plant maize in the same hole with the cowpeas because cowpeas contain a component that prevents the striga from sprouting and damaging maize plants." She further explained that striga does not grow where millet and cowpeas are produced so much as where maize, and beans are.

A participant in Vihiga County acknowledges that intercropping is common because of land sizes that are too small to accommodate monocropping. The most common intercropped crops in the three counties are maize, beans, cowpeas, and sorghum. A male informant in Kisumu explains the varied reasons given by farmers who practice intercropping. First, farmers feel that when intercropped, "if one crop fails, they will get produce from another one." In addition, farmers receive training on the importance of nitrogen-fixing bacteria in soils brought about by planting legumes, "bringing back the soil to its normal state." A key informant in Vihiga concludes, "We want to incorporate crops that can fix nitrogen or have enough biomass to be recycled into the soil. We work with many other organizations that have introduced farmers to crops with many biomasses, like soya beans and lablaba (hyacinth bean)."

Despite intercropping gaining momentum, some farmers feel it hurts crop production. Crops will always fight for nutrients, according to a man in Kajiado, who states that "most of the time, growing maize in November without intercropping will result in a larger harvest than intercropping with beans since the crops will compete for the same nutrients." A woman in the county who has subdivided the farm with each portion having a different crop type says she did so because "We used to mix, but then we realized that when we intercrop, for instance, maize and beans, the harvest will not be good. So, we divide the farm and plant beans, potatoes, and maize [separately]."

Farmers also widely practice organic farming across the three study sites. Many farmers perceive that the application of inorganic fertilizer has failed to increase yields, and this has led to an increased uptake of organic agriculture. Many groups in the communities also promote organic farming as an alternative to applying inorganic fertilizers. A man in Kajiado states, "We have been educated to stop using the chemical fertilizers and instead use the animal manure in the farms. We get influenced to use chemical fertilizers when we see a neighboring farm has used it and got a lot of harvests. Those fertilizers ruin the farms." A woman farmer in Vihiga County echoed this perception by explaining, "What contributes to this is the use of inorganic fertilizers which has destroyed soil fertility.... We have continuously practiced agriculture on our farms. The constant use of fertilizers has also destroyed our soil's fertility."

Farmers use different practices for organic farming. Animal manure is the most common organic material used by smallholder farmers. One farmer noted, "Keeping livestock provides us with waste manure, which adds nutrients to the soil. Even if the soil fertility is low, the waste manure helps the farm regain fertility." The use of animal manure is common because most households own livestock. Cows are the most common livestock, followed by sheep, goats, and chickens. In addition, farmers in the study sites utilize kitchen waste as another source of manure for the farms.

Besides the use of animal waste, farmers recycle maize stalks after harvest and let them rot on the farms instead of burning them. One female farmer in Vihiga County noted this is done "after harvesting maize, the stalks should be left in the garden to decay and help improve soil health ...." A male interviewee adds that the County Government of Kisumu has been encouraging farmers to use rabbit manure for topdressing as "agricultural officers say it is like manure sprayed on vegetable roots."

Digging compost pits is a widespread practice used to prepare organic compost manure. A woman participant in Kisumu states that it takes up to six months for the manure in compost pits to be ready for application on the farm. Contrary to the common misconception that the compost pit only has cattle manure, it has other raw materials such as "chicken waste, tree cuttings, leaves, kitchen waste, and dry maize stalk." The main challenge has been a lack of expertise among farmers, leading to the application of compost pit organic manure before it is ready, lack of adequate raw materials, especially cattle manure, which is the primary raw material, and underutilization of inorganic fertilizer, which, when combined with organic fertilizer, enhances productivity.

Digging terraces and trenches are an additional nature-based solution designed to prevent soil erosion on lands in steeply sloped areas. Through extension services, farmers in Kajiado are trained to not only dig trenches but "plant Napier grass as it controls soil erosion by spreading its fibrous deep roots and when it grows it is an important fodder grass for the cows." In Kisumu, after digging trenches, sugarcane and some trees are planted along these trenches to prevent soil erosion. Water availability in these trenches ensures the crops grown have enough water. A female participant in Kisumu highlights the importance of terraces as "they conserve water, which is used for farming on sunny days. The terraces also protect the soil from being eroded." In Vihiga County, most farms are along the slopes, and building terraces is a widespread practice that prevents running water from carrying topsoil, thus causing soil erosion.

To combat deforestation and the clearing of trees for agricultural activities, communities have planted forest and fruit trees on private farms where a section of the farm is set aside for trees or planted around the farm to demarcate the farm's boundary. A woman in Kisumu states, "One way that conserves the environment is by planting trees because they attract rainfall. We have an artificial forest, and people have planted trees, eventually growing into a forest." A man

farmer in Vihiga County explains the importance of bougainvillea trees, which "make the environment better and appealing and conserve water." Access to extension services has increased farmers' knowledge of the benefits of agroforestry in Kajiado: "there is agroforestry where you grow trees on your farm, and at the same time, you grow your crops. So that tree prevents erosion, and acts as windbreakers, thus protecting crops from damage by intense winds."

Even though more farmers have resorted to planting trees to demarcate their farms, this has done little to reverse the negative effects of climate change. To halt and reverse depletion of forests and water resources, community-led associations have been working with government agencies. Farmers, legal loggers, and KFS work together to ensure that trees are planted and harvested at the right time. In the past, community members were allowed to graze and collect firewood without restrictions. However, this has changed with members expected to pay a fee to use the forest.

There have been changes in management of water as an important community resource. In Kajiado County, Water Resource Users Associations (WRUAs) were established to help maintain water sources. Community members using the water are expected to pay a certain fee to maintain the water source (e.g., a borehole). Maintenance includes repairing and replacing broken pipes and solar water pumps. In Kisumu, the association oversees managing rivers where they control sand harvesting and farming along the riverbanks. To reduce declining water quality due to human activities, the association frequently patrols the riverbanks to stop community members from washing clothes in the rivers.

To help protect water sources, communities in Kajiado formed Water Resource Users Associations (WRUAs). They mainly "protect water sources in the surrounding areas by teaching the community about the methods they can adopt to ensure the quality of water is maintained." WRUAs also organize terracing on farms. They have committee members in charge of ensuring that the members' farms get water via the channels of their terraces. In Kisumu, management of water sources applies to boreholes that nongovernmental institutions have dug. Apart from managing these water points, the committee "does maintenance. Sometimes, they sell the water and collect money to be used for maintenance." Chiefs and village elders head these committees, and all community members must be involved in maintaining and cleaning the water points.

Respondents also discussed the benefits of nature-based solutions. The consensus was that farmers are likely to adopt NbS that provides for the social and economic wellbeing of communities and households. Farmers perceived that NbS being promoted in their communities does provide benefits. In Kajiado, farmers reported increases in harvests and a further impact on household food security. One participant said "If we use the means we have been taught, the plants add its produce. The harvest increases. The plants are also able to withstand the weather." In addition, one male farmer stated: 'My family and the community benefit because the food we

will get, I will not be using it a lot. We will get enough food; I will also get income for my children's school fees and be able to do some development at home. Buy a cow that I did not have. That milk will benefit others, too. When I sell the milk, it will also help the community. If I also sell the harvest, it will benefit the community since those who did not farm will buy it because they need food."

In Vihiga, it was reported that women can earn extra income from the application of NbS which increases their economic empowerment and financial wellbeing. For example, a female participant noted "It is women who benefit because after harvesting I can sell maize and pay my merry-go-round [group savings and loan] contribution. If I have chicken, I can sell and benefit...additionally, [I can] improve crop production and this means that the woman can sometimes sell the crops to make income and will not be asking for financial support from the husband. The man benefits more than the woman because when the harvest is good, it means more money, and the man will always request the woman to give them the money."

Across the three counties, women are engaging more actively in agriculture than men and are, therefore, considered to be more willing to target to adopt nature-based solutions quickly. For example, a man in Kajiado County explains that women are more receptive to such practices and "training them increases the chance of application of the new practices such as the use of manure in improving soil fertility." A female participant in Kajiado further describes how women use kitchen gardens to grow vegetables for household consumption and sell surplus at the market. She adds, "Men think about the bigger things while women think about the smaller issues that can be practiced fast."

However, women do not have full autonomy in making decisions related to agricultural production, as some farming activities cannot begin without the approval of the household head. This can limit their ability to adopt NbS, even on plots that they manage. Women also have a heavier burden of domestic responsibilities, which can prevent them from participating in training or allocating more time to agricultural practices. In addition, some men prevent women from cultivating their own plots of land. A female participant in Vihiga states that, at times, they want to adopt the environmentally friendly practices promoted by different organizations, but their husbands prevent them from doing so. A key informant in Vihiga explains that women's adoption of nature-based solutions lags men's because of a lack of knowledge, given that extension officers typically engage with the man as the head of the household, even if they are not engaged in farming. However, the practice is changing as training is done in groups "where most group members and attendees are women [...] Among the ten people attending, seven are women and three are men."

Both governmental and nongovernmental organizations have been working with communities in Kisumu, Vihiga, and Kajiado Counties in implementing nature-based solutions. These organizations work with community groups such as women's groups to reach a bigger audience

and encourage women's uptake of nature-based practices. For example, the Worldwide Fund for Nature (WWF) has promoted digging terraces, planting fruit trees, and forest restoration in Kajiado County. World Vision has been working with smallholder farmers in Kisumu County to provide critical farm inputs, such as plowing machines and animals, water pumps, pipes, and nets for tomato farmers, and has improved water availability by sinking boreholes and working with community water associations to maintain these waterpoints. The Alliance of Bioversity and CIAT (ABC) is working with communities in Kisumu and Vihiga Counties to set up seedbanks to maintain and store different varieties of seeds that farmers may use during the planting season. ABC has also been training local farmers on fertilizer usage, crop rotation, and diversifying production to include traditional leafy vegetables instead of just relying on kale and cowpeas leaves. Practical Action is actively working with farmers in Kisumu County to capacity building for seed selection and improving nutrition using kitchen gardens. One Acre Fund has been working in the western part of Kenya for several decades; training farmers on proper spacing of seeds during planting to ensure optimum use of the lands especially in Vihiga County where farmers have small land portions. Other organizations active in the study communities include Care International, Vi-Agroforestry, GIZ, KALRO (Ministry of Agriculture), ICRAF-CIFOR, and several community-based organizations.

Despite the efforts of these organizations and initiatives, more widespread adoption of NbS faces several challenges. In the study, we found that knowledge and financial resource constraints limit sustainable adoption of practices, such as water harvesting. There are also climate variability issues linked to water shortages. There are also challenges like declining soil fertility and hence the need for inorganic chemicals like fertilizers. Although the use of inorganic fertilizers may restore soil fertility or increase crop yields, they are associated with unsustainable agriculture and environmental pollution issues have been raised (Penuelas et al. 2023; Savci 2012). The challenges can however be addressed, and their impact lessened through tapping into the prospects that social capital offers.

One of the main challenges is the need for more knowledge and finance to undertake water harvesting. Construction and purchase of water tanks are costly, leaving communities with no option for harvesting water. A male respondent in Vihiga said: "For a family that would require around 5,000 liters of water during the dry season, constructing that storage tank will be more than Ksh.30,000. It is expensive for a smallholder farmer."

## 5.0 Discussion and conclusions

The study sought to assess the social, economic, and institutional characteristics and dynamics associated with sustainable agriculture, specifically the adoption of nature-based solutions (NbS) that are part of nature-positive agrifood systems. Regarded as a pathway to environmental and agricultural sustainability and with positive implications for human health, nutrition, and livelihood outcomes, the transition to nature-positive agricultural systems does not follow a linear path. Instead, it is a complicated process requiring place-based research to identify entry points and drivers of food system sustainability for both people and the planet. To better understand the drivers of change toward more nature positive production, this study assessed the environmental, social, institutional, and economic characteristics and trends in three counties of Kenya as well as the linkages between current agricultural production practices and environmental, social, and economic outcomes. It also explored farmers' awareness and perceptions of NbS, and the challenges preventing more widespread adoption of these practices. Significant attention was paid to gender inequalities and dynamics in environmental and agricultural systems in the study sites and the implications for the adoption of NbS.

The study found that the natural resources that the communities rely on have been deteriorating over time, leading to declines in agricultural production and threatening rural livelihoods. Deforestation due to land clearing for agriculture has led to significant forest cover loss, threatening these resources which communities depend on for fuel, income, and livestock feeding. Similarly, water resources are threatened by climate change with some rivers drying up during periods of the year, which negatively affects access to irrigation and water for livestock and other productive and domestic purposes. Farmers also perceived water quality declining, contributing to many human health challenges. Land degradation due to declining soil fertility and erosion is also a significant challenge affecting agricultural productivity and livelihoods in the study sites.

While farmers recognize these challenges, there are clearly tradeoffs between the desire to protect natural resources and meet basic needs. For example, while charcoal production is an important income earning activity for many households, it contributes to deforestation over time. There is often a mismatch of incentives that drives individuals to continue to engage in unsustainable practices like monocropping. Farmers may be unlikely to adopt NbS if they do not receive economic benefits in the near term, despite acknowledging the negative impact of current practices on the environment. Additional challenges that hinder the widespread adoption of NbS include limited knowledge about NbS, inadequate financial resources, and climate-related challenges, such as increasingly unpredictable rainfall patterns leading to water shortages.

In terms of nutrition, study participants perceived that agricultural systems were producing a diverse set of foods that would enable consumption of diverse diets. They attributed poor nutritional status to lack of awareness of dietary guidelines and understanding of the importance

of eating a diverse diet and consuming healthy foods such as leafy greens and other vegetables along with maize-based staple foods. Addressing this challenge will require more widespread training on nutrition and healthy diets.

Various institutions, both formal and informal, are instrumental in promoting sustainable natural resource management. The study identified several organizations working in the three counties to promote uptake of NbS. For example, agencies such as the Kenya Forest Service and community forest associations have been actively working to restore and conserve forest cover by encouraging reforestation and community-led forest management. In Kajiado, both men and women are now involved in creating tree nurseries and planting trees, showing a shift in traditional gender roles. In addition, local organizations and community groups are educating farmers about sustainable practices and organizing collective action, such as tree planting and soil conservation initiatives. Moreover, institutions like the water resource users' associations play a vital role in safeguarding water resources and ensuring equitable access for communities.

As a result of these efforts, farmers in the study communities are aware of many NbS and are gradually adopting nature-based practices, such as crop rotation, intercropping, organic farming, and soil conservation techniques like terracing. These practices have proven effective in restoring soil fertility, enhancing crop yields, and increasing household food security. For example, farmers in Kajiado reported significant improvements in harvests after adopting soil conservation methods, which directly contributed to food security at the household level.

However, the number of different organizations operating in the study sites can also lead to confusion and even misinformation being spread. For example, research shows that inorganic fertilizers, when appropriately applied along with organic matter, have benefits for soil health and can contribute to GHG reduction. Farmers in the study sites are under-applying inorganic fertilizers due to the high cost of this input and recent challenges with poor quality or even counterfeit fertilizers flooding the market. Promoting organic farming may be a suboptimal approach to address this challenge—rather, ensuring farmers have access to soil testing and quality fertilizers would be a more effective solution. In addition, correct application and micro-dosing of fertilizers are important practices for which farmers need information and training. There is a need for improved extension services to provide this kind of information and advice, as well as training and technical support to implement sustainable practices. Kenya's extension services are pluralistic with public and private providers. Public extension needs to provide advice and support on public goods and regulate and coordinate nonpublic providers.

Moreover, women face additional constraints in adopting NbS, particularly given their more limited influence over agricultural decisions and lack of access to and control over key resources such as land. This implies the need to target women with information and resources (e.g., technologies, access to land) needed to facilitate their uptake of practices that they prefer and that meet their needs. Greater effort is also needed to promote women's empowerment so that

they have greater agency to influence agricultural decisions and adopt NbS. This will require interventions and strategies that seek to include both men's and women's perspectives in the design and implementation of NbS and inclusive governance arrangements that elevate women's voices. However, the study found signs that gender norms are slowly evolving, with women increasingly involved in natural resource governance and activities like creating tree nurseries and participating in community-led conservation efforts.

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## Appendix 1: Codebook

Main themes	Sub-themes
Nature Positive Solutions	<ul style="list-style-type: none"> <li>Nature positive practices</li> <li>Awareness of Nature Positive Solutions (Nature+)</li> <li>Nature+ benefits</li> <li>Nature+ adoption</li> <li>Challenges to Nature+ adoption</li> <li>Incentives to adopt Nature+ practices</li> </ul>
Resource types and study sites	<ul style="list-style-type: none"> <li>Forests</li> <li>Forest management</li> <li>Water Sources</li> <li>Water use</li> <li>Land resource</li> <li>Gender roles and responsibilities in resource management</li> <li>Community resource management committees</li> </ul>
Current farming system	<ul style="list-style-type: none"> <li>Crops and fruits grown</li> <li>Livestock reared</li> <li>Gender roles and decision-making in crops production</li> <li>Utilization of agriculture income</li> <li>Fish farming</li> <li>Gendered livestock ownership</li> </ul>
Change in resource utilization, quality, and availability	<ul style="list-style-type: none"> <li>Climate change</li> <li>Deforestation</li> <li>Effects of agricultural activities on forest cover</li> <li>Government ban on illegal logging</li> <li>Change in water quality- pollution of water sources</li> <li>Unsustainable agricultural practices</li> <li>Soil erosion and land degradation</li> <li>Community Health Volunteers (CHVs)</li> </ul>
Nutrition and Food Security	<ul style="list-style-type: none"> <li>Sources of good nutrition</li> <li>Change in diets over time</li> <li>Gendered consumption of food</li> <li>Prioritization of nutritious food</li> <li>Malnutrition</li> <li>The most affected by malnutrition</li> <li>Source of nutrition information</li> <li>Challenges</li> </ul>

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