ETHNOBIOLOGY AND CONSERVATION

RESEARCH ARTICLE

Ethnobiology and Conservation, 14:27 (30 July 2025)
doi:10.15451/ec2025-07-14.27-1-37
ISSN 2238-4782 ethnobioconservation.com

Assessing Indigenous Knowledge on Diversity, Socio-economy, and On-Farm Management Practices of Yam Landraces (*Dioscorea cayenensis-rotundata* Complex) for Sustainable Production in Southern Ethiopia

Birhanu Kagnew[1,2,*], Awol Assefa[2], Messay Mulugeta[3], Asfaw Degu[2], Wondawek Abebe[4] and Sebsebe Demissew[2]

ABSTRACT

World's agriculture mainly relies on cereal crops (e.g., wheat), often overlooking tuber and root crops like yams. Yams are nutritious, staple foods, climate-resilient, and vital for food security, especially in Sub-Saharan Africa and Southeast Asia. Ethiopia's yam production is crucial for sustainable agriculture, improving nutrition, and significantly enhancing food security. Agricultural interventions that prioritize cash crops, given less attention at regional and national level, threaten yam diversity maintenance, production and weaken the local indigenous knowledge of the yam-based agriculture system in Ethiopia. This study explores yam on-farm management practices, conservation, production constraints, socio-economic significance, and indigenous farming knowledge of farmers. The study involved 1125 households in three districts and 14 Kebeles, using interviews, questionnaires, focus group discussions, and landrace counts at farm levels. A two-way ANOVA ($p<0.05$), Shannon diversity index, evenness, Simpson's diversity index, and Sorenson's similarity index were used to analyze the distribution and diversity of yam landraces. The main production constraints are biotic and abiotic stress factors, including drought and climate change (97.78%), lack of sustainable seed source (95.64%), market chain issues (92%), high production costs (87.91%), labor cost (73.51%), disease and animal attack (95.64%), lack of staking materials (98.76%), tediousness of the practice (95.29%), farmland scarcity (96.27%), lack of training (98.93%), lack of awareness (72.53%), lack of modern storage (84.44%), lack of agro-chemicals (99.73%), lack of new technology (68.44%), lack of credit access (95.56%), and lack of optimized fertilizer rate as well as less attention given to the crop at regional and national levels become the problems for maintenance and production of yam. The majority of yam seed tuner sources come from previous harvests, while local indigenous knowledge is being utilized in fertilizer application and yam farming. Despite, strong preferences for yam production (70.93%), trends indicate a decline (77.51%) due to the factors mentioned above. The study recorded 27 yam landraces, with Basketo Zone exhibiting the highest diversity (H = 25.9), followed by Daramalo (H = 16.6) and Offa (H = 16.15) districts. Interims of Kebeles, Wadha Kebele of Basketo zone revealed the highest yam landraces diversity (H=4.529) while most landraces was common across Kebeles' within each districts. The organization of yam landrace communities is undergoing significant changes due to both natural and human-induced disturbances across all study sites. Consequently, currently, most yam landraces are now cultivated in small plots by a few farmers, highlighting the need for interventions that support on-farm conservation while aligning with farmers' interests to preserve yam diversity.

Keywords: Conservation, Dioscorea cayenensis-rotundata Complex, Ethiopia, Yam landraces, Local knowledge, Livelihood.

1 Department of Biology, College of Natural and Computational Science, Hawassa University, P.O. Box 05, Hawasssa, Ethiopia.

2 Department of Plant Biology and Biodiversity Management, College of Natural and Computational Sciences, Addis Ababa University, P.O. Box 3434, Addis Ababa, Ethiopia.

3 Addis Ababa University, College of Development Studies, Center for Food Security Studies, P.O.B, 1176, Addis Ababa, Ethiopia.

4 Department of Microbial, Cellular and Molecular Biology, Addis Ababa University, P.O. Box 1176, Addis Ababa, Ethiopia.

* Corresponding author ✉. E-mail address: BK (birhank444@gmail.com)

SIGNIFICANCE STATEMENT

This study explores the novel Local Indigenous Knowledge (LIK) on yam diversity, socio-economy, and on-farm management practices in Southern Ethiopia, aiming for sustainable production and food security. It documents traditional sustainable yam production practices and conservation, highlighting their cultural, socio-economic, and medicinal importance. This work bridges gaps in understanding indigenous yam farming systems and contributes significantly to yam sustainable production, ethno-biological study and yam biodiversity conservation. Thus, this research underscores the importance of promoting the traditional yam farming system as a key solution to adapt to climate change, conserve agro-biodiversity and ensure food security by highlighting sustainable production strategies and conservation initiatives for subsistence farmers, policymakers, and biodiversity conservation initiatives.

INTRODUCTION

Worldwide, millions of people suffer from food insecurity and various forms of malnutrition as a consequence of the high cost of healthy diets in many low and middle-income countries (FAO 2021). Hunger prevalence increased from 8.4% in 2019 to 9.9% in 2020, affecting up to 811 million people, accounting for 10% of the global population, with the majority of these people located in Sub-Saharan Africa, Southeast Asia, Caribbean, and parts of Latin America (FAO 2021).

Multiple factors exacerbate food insecurity, particularly in developing countries. These include environmental degradation, poor soil fertility, climate variability and extremes, economic slowdown turns or crisis, pests, population growth, poverty, rural-urban migration, and conflicts are factors that have exacerbated food insecurity, particularly in developing countries (FAO 2021). In Ethiopia, rain-fed agriculture, recurrent droughts, poor soil fertility, poverty, lack of access to new technology, conflict, biotic and abiotic factors (Agidew and Singh 2018; Demilew 2022), and poorly tailored environment policies that do not cater to the needs of small-holder farmers (Demilew 2022) are among the main contributors to food insecurity.

At the household level, food insecurity in Ethiopia is influenced by variables such as farm size, farming systems, land quality, technology adoption, family size, cattle ownership, access to markets, and off-farm income (Feleke et al. 2005). The poor performance of Ethiopia's agricultural sector further compounds issues of food access and poverty (Temesgen and Rashid 2009). As net revenue per hectare declines due to climate change and other challenges, poverty rates rise (Temesgen and Rashid 2009). However, Ethiopian small-scale farmers who face fragmented farmlands and recurrent drought are struggling to produce sufficient crops to meet the rising food demands of the population (Agidew and Singh 2018).

To enhance food security in Ethiopia, it is essential to reduce dependency on rain-fed agriculture and promote climate-resilient crops. Diversifying cropping systems and incorporating underutilized, nutritious, and drought-tolerant root and tuber crops like yams is a promising strategy (Demilew 2022).

Ethiopia's diverse agro-ecologies support the cultivation of cereals and a wide range of root and tuber crops, such Teff (*Eragrostis tef* (Zucc.) Trotter), Maize (*Zea mays* L.), Wheat (*Triticuma aestivum* L.), and Millet (*Panicum* spp.), Enset (*Ensete ventricosum* (Welw.) Cheesman), sweet Potato (*Solanum tuberosum* L.), Taro (*Colocasia esculenta* L.), Yams (*Dioscorea* spp.), Anchote (*Coccinia abyssinica* Lam), Cassava (*Manihot esculenta* Crantz), Tannia (*Xanthosoma sagittifolium* L.), and Sweet potato (*Ipomoea batatas* L.) (FAO 2009). These crops play a critical role in food security due to their resilience to poor soils, drought, and other stresses (FAO 2009; Pascual et al. 2011; Massawe et al. 2015; FAO 2018; Demilew 2022). Maintaining and promoting agro-biodiversity by integrating underutilized crops enhances nutrition and supports smallholder livelihoods. Yams, in particular, offer substantial benefits in terms of sustainability and resilience to climate change (Pascual et al. 2011; Massawe et al. 2015; Wendawek et al. 2021). Hence, farmers can take advantage of the benefits that can be derived from neglected and underutilized roots and tuber crops like yams (Wendawek et al. 2021; Demilew 2022), which foster sustainable agriculture.

Yams (genus *Dioscorea*) comprise approximately 600 species (Norman et al. 1995; Miege and Sebsebe 1997; Hildebrand et al. 2002; Sebsebe et al. 2003), with 50–60 species used for food and medicine (Norman et al. 1995; Miege and Sebsebe 1997). Yams are an excellent source of income, food, and medicine, and have significant socio-cultural value (Bhandari et al. 2003; Mignouna et al. 2008; Muluneh et al. 2011; Nweke 2016; Frossard et al. 2017; Baressa and Itefa 2019; Lebot et al. 2019; Tizazu 2019; Mulualem et al. 2022; Matsumoto et al. 2021; Wendawek et al. 2021). Yam is nutrient-rich (Massawe et al. 2015; Nweke 2016) and serve as a source of carbohydrates, proteins, lipids, minerals, and pharmaceutical materials (Bhandari et al. 2003). It also supports the livelihoods of over 300 million people in tropical and subtropical regions (Mignouna et al. 2008). Despite these benefits, yams remain underutilized in research and development efforts, especially regarding their potential to enhance food security and income (Mignouna et al. 2008).

In 2020, global yam production reached 74.5 million tons, with Nigeria contributing 67% of this total (Scott 2020). African countries account for 96% of global yam production, with Nigeria (71%), Ghana (9%), Côte d'Ivoire (8%), Benin (5%) and the rest of Africa (7%) as major producers (https://www.fao.org/4/y9421e/y9421e05.htm). From 1961 to 2018, production increased by 88% (5.9 to 72.9 million), mainly in (50.1 million tons), Ghana (8.5 million tons), and the Côte d'Ivoire (7.7 million tons) (Scott 2020). In contrast, East and Central Africa's combined yam production remains below 10%, revealing a stark regional disparity in productivity (FAOSTAT 2020). Ethiopia, despite its vast arable land and diverse yam landraces (Demilew 2022), produced only 45,730 tons in 2020 (CSA 2021). However, the availability of a diverse landrace, large arable lands, and newly released varieties promise an improvement in Ethiopia's yam production (Demilew 2022).

Ethiopia's yam production faces multiple constraints: policy neglect, insufficient attention, soil degradation, as well as abiotic and biotic stress (Muluken et al. 2008; Wendawek et al. 2021; Mulualem et al. 2022; Demilew 2022). Increased land pressure, moisture stress, diseases, and pests limit the sustainable production and income generation of yam for subsistence farmers (Tchabi et al. 2010; Matsumoto et al. 2021; Wendawek et al. 2021). Modern agricultural practices like shifting towards cash crops productions, further threatening yam farming's sustainability (Tizazu 2019; Wendawek et al. 2021). These challenges limit yam's contribution to food security and income generation.

Ethiopia is home for 11 *Dioscorea* species, including *D. cayenensis* Lam., *D. rotundata* Poir., *D. abyssinica* Hochst. exKunth., *D. praehensilis* Benth., *D. sagittifolia* Pax, *D. alata* L., *D. bulbifera* L., *D. schimperana* Kunth., *D. gillettii* Milne Redh, *D. dumetorum* (Kunth) Pax, *D. quartiniana* A.Rich. and *D. cochleari-apiculata* De Wild which are widely grown in various parts of the country (Miege and Sebsebe 1997; Hildebrand et al. 2002), with significant genetic diversity reported in southern and southwestern parts of Ethiopia (Miege and Sebsebe 1997; Muluken et al. 2008; Wendawek et al. 2021). A single study (Wendawek et al. 2021) alone identified a total of 33 unique farmers' yam landraces from the Basketo Special Zone (24 records), the Wolayta Zone (11), and the Gamo Zone (8), with 22 (61.11%) unique to the Basketo Special Zone, 3 (8.8%) to the Wolayta Zone, and no unique type from the Gamo Zone. A research by Muluneh et al. (2007) assessed the genetic diversity of 48 Ethiopian yam accessions using AFLP markers and found that 97% of the landraces were polymorphic, indicating high genetic variability. Furthermore, 81% of the variation was found within collecting areas, suggesting localized adaptation and limited gene flow (Muluneh et al. 2007). Mulualem et al. (2022) identified 38 distinct yam landraces named by farmers, highlighting the rich genetic diversity present in the southern Ethiopia. These landraces exhibit a wide range of traits, including variations in tuber size, shape, skin and flesh color, and culinary qualities (Mulualem et al. 2022).

Yam, a staple crop in Ethiopia, is traditionally grown by subsistence farmers alongside enset, cereals, and other root crops. It supports local livelihoods, especially in densely populated, remote, and forested areas, by providing food, income, and traditional medicine during times of agricultural failure and food scarcity (Hildebrand et al. 2002; Sebsebe et al. 2003; Muluneh et al. 2008; Baressa and Itefa 2019; Tizazu 2019; Tsegaye 2021; Wendawek et al. 2021; Demilew 2022). Yet, agricultural interventions prioritizing cash crops, along with shrinking household landholdings, threaten yam diversity and deteriorate the local indigenous knowledge (LIK) of the yam-based agriculture system, hindering its transfer to younger generations and potentially causing the irreversible loss of agro-biodiversity (Wendawek et al. 2021). However, in Ethiopia, farmers have identified and preserved a diverse array of landraces, adapting cultivation practices to local agro-ecological conditions (Muluneh et al. 2007). Farmers' preferences for yam traits vary, with the most valued characteristics being high yielding, disease and drought resistance, market demand, maturity (early/late), harvest (double/single, quality of tubers, medicinal values. These LIK are significantly essential for conservation efforts and breeding (Wendawek et al. 2021; Mulualem et al. 2022). Farmers' perceptions of local varieties are critical because they are not only the unit of diversity that they recognize, but also the unit that they manage and conserve (Hildebrand et al. 2002; Sebsebe et al. 2003; Muluneh et al. 2008; Wendawek et al. 2021). They have developed and maintained a large number of yam landraces for centuries based on their traditional knowledge. Thus, the knowledge of agricultural biodiversity and conservation in Ethiopian yams is found mainly with the local farmers (Hildebrand et al. 2002; Sebsebe et al. 2003; Muluneh et al. 2011; Wendawek et al. 2021).

Several studies often highlight the existence of great yam diversity in Ethiopia but falls short of examining strategies for conserving it amidst these challenges by evaluating the role of IK in maintaining yam biodiversity and identifying interventions that support both conservation and productivity. Furthermore, despite the acknowledged value of LIK in promoting agricultural sustainability and crop diversity, its role in yam diversity, socio-economic significance, and on-farm management in Ethiopia has received limited attention. Most existing research focuses on staple crops, creating a knowledge gap regarding how indigenous practices support yam preservation, productivity, and socio-economic importance within Ethiopia's varied cultural and ecological settings. This study seeks to address these gaps by exploring and documenting LIK systems associated with yams and their potential integration into sustainable agricultural practices. The findings will benefit the subsistence farmers, policymakers, and biodiversity conservation initiatives by offering strategies for sustainable production and conservation.

MATERIAL AND METHODS

Study Area

The study was conducted in the Basketo Special Zone, Daramalo, and Offa districts of Ethiopia, areas known for extensive yam cultivation (Figure 1). Basketo is located on a plateau at an altitude 700-2200 m (6°15'0.0" N, 36°34'60.0" E), with its main town being Laska. The district has a population of 56,689 (28,532 men and 28,157 women (CSA 2007), predominantly inhabited by the Basketo ethnic group (87.75%), with smaller proportions of Wolayta, Amhara, and Konso people. The Zone is well known for its diverse agro-climates from lowland to highland (700-2200m.a.s.l.), which support the cultivations of various crops, including spices, cereals, roots and tubers like yams (Wendawek et al. 2021). The diverse vegetation types including home-gardens, forests, and agro-biodiversity with both cultivated and wild plants are shaped by altitude and climate. The mean annual rainfalls, as well as the maximum and minimum temperatures of the three study areas, are presented in Figure 1 below.

The Daramalo district (1745 m, 6°19'10.2" N, 37°21'7.2" E, Figure 1), located in the Gamo Zone, has Wacha town as its administrative center and is primarily inhabited by the Gamo people. The district has a population of 81,025 (41,618 men, 39,407 women) (CSA 2007).

Offa district (1200-2800 m, 6°44'59.99" N, 37°29'59.99" E, Figure 1), situated in the Wolaita Zone, consists of 21 Kebeles (the lowest administrative unit within the districts in Ethiopia) and has a population of 127,387, 51.5% of whom are women (CSA 2007). Gasupa town serves as its administrative center. The district is primarily inhabited by farmers who mainly grow yams, although to a lesser extent than the other district (Wendawek et al. 2021).

The three districts (Basketo, Daramalo, and Offa) share similarities in their ethno-linguistics (Omotic origin), agricultural systems, and reliance on staple foods such as enset and tuber crops like yams. The diverse soil types, bimodal rainfall patterns (March–May, September - November), warm climate, and temperature range (18°C–25°C) are conducive to yam growth in the Basketo Zone, and Offa and Daramalo districts (Figure 1) (Tizazu 2019). In these districts, yams are predominantly cultivated across low-to-high-altitude zones; 1350–2200 m (Muluneh et al. 2011) and 1300-2300m (Wendawek et al. 2021) alongside with other tuber crops, cereals, pulses, and vegetables (Wendawek et al. 2021). These crops are grown using traditional agronomic practices deeply rooted in local culture, including intercropping, the application of organic fertilizers, and an adherence to specific planting times (Muluken et al. 2011; Wendawek et al. 2021). Yams serve as a staple food in these districts, contributing significantly to food security, and are primarily consumed in boiled form. Yam farming is shaped by the interplay of favorable climatic conditions, suitable soil types, and rich cultural traditions that guide agricultural practices and consumption patterns (Wendawek et al. 2021).

Data sources and types

The study utilized both primary and secondary data sources. Primary data were gathered from yam-growing farmers, district agricultural experts, key informants through interviews, questionnaires, focus group discussions (FGDs), and field observations. Secondary data sources included published articles, books, and unpublished documents from district agricultural officers (WAOs).

Sampling technique and procedure

Before the actual data collection began, a field survey was conducted in the Basketo Special Zone, and the Daramalo and Offa districts (Figure 1; Table 1), with the guidance of district agricultural developmental agents (DAs) to identify yam-growing areas in 2023. The survey included field observations to evaluate the study area's significance regarding yam diversity, distribution, management, and associated production constraints. Activities such as transect walks through home gardens and cultivated fields, interviews with key informants, and informal dialogues with farmers were conducted. These approaches helped to gather information on yam production and related issues, enabling the collection of general data about the study area and the identification of representative sampling sites. Districts, Kebeles and farmers were selected purposively based on the reconnaissance survey results, information obtained from key informants, yam production potential, and a prior assess-

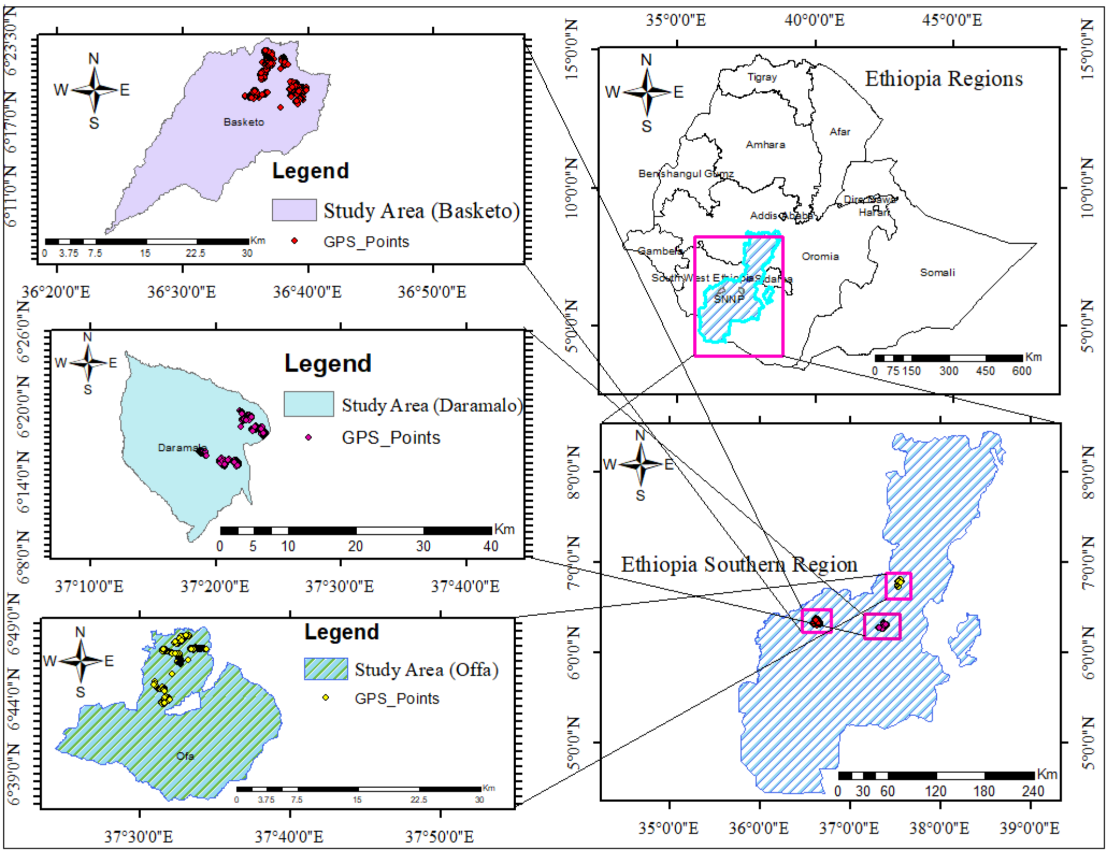


Figure 1. Map of the geographical locations of the study area (left), and climadiagram (right) for rainfall (2000-2020) and temperature (2015-2020) of the study areas. Source: Ethiopian National Meteorology Institute, Hawassa Station, 2023, Ethiopia.

ment study conducted by Wendawek et al. (2021). A total of 14 Kebeles were selected from the three districts (Table 1). Household lists of each Kebele within each district were collected and used to distribute the sample size among the sample Kebeles. Representative households were then selected using a systematic random sampling method (Table 1) to ensure fair representation across the study area.

An equal proportion of household's representation from the villages was considered by taking 5% sample households. The sample interval (nth) was calculated by dividing the total number of households in each district by the sample size. Respondents were randomly selected based on the nth interval, with the first number chosen as the basis to serve as the starting point.

Sample size determination

The representative sample size (Table 1) was determined based on the total population of each district. The sample size for this study was calculated using (Kathari 2004)'s formula at a 95% confidence interval with a 5% significance level. The formula used to determine the sample size is as follows.

Sample size:

$$n = \frac{N}{1 + N \cdot (e) \cdot 2} \quad (1)$$

. Where: n = sample size to be studied, N = population size, e = level of precision (margin/sampling error) at 5% (0.05) where the confidence level will be 95%. "1" is Kebeles probability of the event occurring. The representative sample size at each kebele level was calculated using the following formula.

$$k = \frac{n \cdot Pi}{N} \quad (2)$$

.where "n" is the sample size selected from the sample Kebeles of each district selected for this study, Pi is the number of households in the respective Kebeles, N represents the total households of the Kebeles, and k is sample households of each kebele (Table 1). Accordingly, 1125 households were sampled from the total household population (42,128) of 14 selected Kebeles and the three districts using the above formula (Equation (2)). The study highlights the significance

Table 1. Total households (HH), elevation, and sample sizes of each Kebeles' of the study areas.

Districts	Kebeles'	Elevation (m.a.s.l)	Total HHS in Kebele (N)	Sampled HHs (k)	Total sampled HHs (n)
Basketo Special Zone	Wadha Balanssa	1777-1906	1,672	102	376 (33.42%)
	Sassa Malkesa	1772-1874	929	56	
	Doko Chorie	1798-1928	902	55	
	Debtsa Dalkinsa	1758-1935	1,298	79	
	Garbeya	1750-1827	414	25	
	Shella Kanibolla	1804-1952	965	59	
Daramalo district	Dara Dime	1958-2201	1,155	139	395 (35.11%)
	Malo Machie	1917-2091	4,98	60	
	Menena Abaya	1665-2061	8,189	98	
	Menena Selo	1764-2065	8,17	98	
Offa district	Waraza	1725-2118	740	86	354 (31.47%)
	Yakima	1777-2134	682	79	
	Okoto sere	1376-1935	737	85	
	Sadoye	1647-1914	900	104	
Total	14	-	42,128	1,125	1,125 (100%)

of considering different elevations in comprehending the geographical distribution and conservation of yam landraces in these districts (Tables 1, 8 and 9).

Data collection

Both qualitative and quantitative data were collected using questionnaires, semi-structured interviews, key informant interviews (KIIs), focus group discussions (FGDs), field observations, and yam landrace counts (Table 1). KIIs and FGDs were employed to gather qualitative data. These interviews and discussions were conducted with purposefully selected local elders, farmers, officials, and experts on the subject matter. The primary participants targeted for data collection in the study were farmers who cultivated yam within the selected Kebeles (Table 1).

Field observation: Field observations were conducted on farmers' yam farming practices to examine on-farm management, agronomic practices, farming methods, and the associated local indigenous knowledge (LIK), used in the yam farming systems. The observation also aimed to count the number of yam landraces at the farm level. Specifically, the count of yam landraces at the farm level was crucial for estimating the diversity and richness of yam landraces within each district and kebele of the study area (Table 2 and 8-10).

Key informants: Key informants were purposively selected individuals from 14 Kebeles based on their leadership roles, educational backgrounds, LIK, and experience in traditional yam farming systems. From each kebele, one kebele manager, five model farmers, and one developmental agent $(1 + 5 + 1) \cdot 14 = 98$ key informants were involved to explore cultural assets, yam production status, LIK, farm management, constraints, development plan, policy, and challenges for yam production across all 14 Kebeles (Table 2).

Questionnaires: A questionnaire with both closed and open questions was used to gather data from respondents (Table 1 and 2) using Kobo Toolbox, version 2.4 (`https//:www.Kobotoolbox.org`, accessed 27 October 2023), a user-friendly platform that works offline and online, and which provides data access on any device and offers core functionalities for free. The questionnaire was evaluated by experts in the field. Prior to full implementation, a pilot test was conducted to assess the suitability of the questionnaire design for the target population and data collection processes. The questionnaire addresses issues related to yam on-farm management, production constraints, market chains, agronomic inputs, conservation status, socio-economic importance, and the contribution of LIK to yam farming and conservation, targeting farmers actively involved in yams cultivation (Table 2).

Semi-Structured Interviews: Interviews were conducted with selected household heads (Table 1) to gather comprehensive data on the socio-demographic characteristics of the respondents, on-farm manage-

Table 2. Summary of the above-mentioned data collection methods.

Objectives	Method	Expected insights
‘Yam on-farm management	Questionnaire, interview, FGD	Data on farming practices, seed systems, and management strategies etc.
Conservation status	Key informants, questionnaire, interview, field observation	Information on extinct/endangered varieties and conservation techniques.
Production constraints	Questionnaire, FGD, interview	Identification and prioritization of challenges faced by farmers etc.
Socio-economic importance	Questionnaire, interview, FGD	Yam’s role in income, food security, and cultural significance etc.
Indigenous knowledge of farmers	FGD, Key informants, interviews, questionnaire	Documentation of traditional practices, beliefs, and their relevance to yam production etc.

ment (including farming techniques, planting, agronomic inputs, pest control, and harvesting practices), production challenges, LIK (local names, traditional farming, and methods of preservation (in situ)), and socio-economic aspects (income, food security, market access) (Table 2). The interviews allowed for flexibility, enabling respondents to elaborate on their experiences and perspectives. This approach facilitated the collection of both quantitative and qualitative data, offering a holistic understanding of yam cultivation and its significance within the study area, thereby contributing to the overall objectives of the study (Table 2).

Focus Group Discussion (FGD): A discussion was conducted to fill gaps in data collection and explore controversial yam production issues raised by informants. This discussion allowed us to gather information on topics that require in-depth research and analysis (Table 2). Local agricultural extension agents and community leaders were used to identify potential participants based on demographic, geographic locations, and their long-term experience in yam cultivation, farming methods, and farm sizes to provide valuable insights on yam farming systems.

On-farm farmers’ yam landraces diversity and distribution measurement techniques

Yam landrace diversity was measured using the following indices: (i) Shannon diversity index (H’), (ii) Evenness (E), (iii) Simpson’s diversity index (D), and (iv) Sorenson’s similarity index (SI) (Magurran 1988; Simpson 1949). The diversity of yam landraces was measured in terms of richness and abundance. Shannon and Simpson diversity indices were used to evaluate the diversity of yam landraces across study areas, comparing both richness (the number of different landrace types without indicating their frequencies) and evenness (which measures how similar the frequencies of the different variants are) across each district and kebele. Greater evenness indicates a more diverse community (Table 10). Distribution refers to the number of surveyed locations where a landrace is found. These indices were selected for their broad applicability, usefulness in summarizing diversity, and ease of interpretation, especially when applied across various districts and Kebeles (Tables 9 and 10).

i) Shannon diversity index (H’) combines both number and evenness of categories considered, and can be increased either by greater evenness or more unique species. Shannon diversity index $(H') = -\sum_{i=1}^{S} pilnpi$ Where, “s” is number of landraces, and “p_i” frequency or proportion of each landraces i (n_i/N). "ln" is natural logarithm. This index is widely used in ecological and genetic diversity studies because it accounts for both the abundance and evenness of different species in a population. It can provide insights into the overall diversity of a population by considering both rare and common species.

ii) Evenness (E) was also calculated separately as a measure of the ratio of the observed diversity to the maximum diversity. $Evenness(E) = \frac{H'}{ln(S)}$. Where, “H’” is Shannon index and “s" refers to the number of landraces recorded in each district Kebeles. “lns” is a measure of landraces abundance. A value of evenness approaching zero reflects a larger difference in abundance of landraces, whereas the higher evenness value means all landraces are equally abundant with high diversity (Magurran 1988).

iii) Simpson's diversity index (D) measures the probability that two individuals randomly selected from a sample belong to the same category (Simpson 1949). As D increases, diversity decreases, hence, converted as 1-d simply so that more variety corresponds to higher values: Simpson's diversity index $(1-D) = 1-\frac{\sum n(n-1)}{N(N-1)}$ here "n" represents number of farms where landrace i was found, and "N" sum of the number of farms where individual landraces was found. This index emphasizes the probability that two randomly selected individuals from the population will belong to different species or genetic types. It is sensitive to the dominance of a single species and can be useful in detecting the extent of homogeneity or heterogeneity in the population.

iv) Sorenson's similarity index is used to measure the variance in landrace composition that happened between Kebeles. Sorenson's similarity index $(SI) = \frac{2c}{a+b}$ Where, "a" represents the number of landraces in site A; "b" represents the number of landraces in site B; and "c" represents the number of landraces common to both sites. The Sorensen similarity index measures the overlap between two populations by taking the ratio of the number of species shared between the two populations, relative to the number of species in both populations.

Data analysis

This study utilized a combination of quantitative and qualitative data analysis techniques. The collected data were processed, summarized, and analyzed using SPSS version 25. The data underwent a two-way analysis of variance (ANOVA) to identify differences in the mean values of yam landrace numbers recorded across all the study districts and Kebeles, with significant differences considered when $p < 0.05$. Additionally, the Kobo Toolbox software and Microsoft Excel were also used for data analysis. Frequency, percentage, mean scores, and standard deviation were used to present the result. The diversity and richness of yam landraces were also analyzed by calculating the Shannon diversity index, evenness, Simpson's diversity index, and Sorenson's similarity index based on yam landrace count records.

RESULTS

Household's characteristics

The result of household characteristics, such as gender, size, age, marital status, religion, and educational status, are presented in Table 3. The study involved men (91.2%) and women (8.80%), with household sizes ranging from 6 to 10 members (59.20%). The minimum, maximum, and mean household sizes were 2, 11, and 6.37 ± 2.28, respectively (Table 3). The study also found that 50.58% of respondents were aged 36–50, with a mean age of 42.69 ± 10.41 years. Only 1.78% of respondents were aged over 67 years, indicating that the majority of households are in the productive stages of life (Table 3).

The study found that 91.64% of participants were married, and married individuals tended to have greater labor resources and social support. The majority of respondents identified are Protestant (69.16%) and Ethiopian Orthodox Christian (30.84%). Additionally, 46.93% of the respondents were illiterate farmers (Table 3).

Local Indigenous knowledge (LIK) of farmers' related to yam production

Ethiopian smallholder farmers in the study area primarily possess LIK regarding agricultural biodiversity and yam conservation. They predominantly rely on local yam landraces (99.73%) to sustain yam production (Table 4). Farmers select and preserve landraces based on phenotypic and agronomic traits, employing traditional yam propagation methods by cutting large tubers into 150–1000 g sets and planting them in the soil to produce seedlings for the next planting season. This practice increases genetic relatedness among landraces (Tables 8 and 9). Farmers plant tuber seeds during the dry season, anticipating their emergence during the rainy season, due to the lack of advanced propagation techniques. Maintaining yam seeds in the soil during the dry season is a strategy to prevent rotting, sprouting, and consumption losses of yam seeds. Some farmers cultivate a significantly diverse range of yam landraces, from 1 to 9 landraces (Table 8). However, the study reveals a decrease in on-farm landrace diversity across the three districts (Figure 3), possibly due to farmers withdrawing certain landraces and other factors outlined in Table 4-7. Despite production constraints, most farmers (92.18%) rely on LIK to cultivate and conserve yam landraces, ensuring household food security even though production levels often fall below expectations (Table 12). LIK plays a crucial role in conserving the local varieties by focusing on the cultivation of local and indigenous yam varieties better adapted to local conditions, such as soil types, pest pressures, and climate variability. In the Basketo Special Zone, the yam landrace "Yesha" (also called "Bozene") is known for its broad leaves, sour taste, and medicinal use (Additional File 1A). Similarly, "Ochie" or "Ocha," of Daramalo district, is also widely used for medicinal purposes. Ochie or Ocha

Table 3. Household's characteristics of the study area.

Variables	Variable Categories	Frequency	Percentage
Gender	men	1026	91.2%
	women	99	8.80%
	Total	1125	100,00%
Household size (number of people)	1-5	410	36.44%
	6-10	666	59.20%
	10 and above	49	4.36%
	Total	1125	100,00%
Age	20-35	315	28.00%
	36-50	569	50.58%
	51-66	221	19.64%
	67 and above	20	1.78%
	Total	1125	100,00%
Marital status	Married	1031	91.64%
	Widowed	53	4.71%
	Divorced	18	1.60%
	Single	15	1.33%
	Polygamy	8	0.71%
	Other	-	0.0%
	Total	1125	100,00%
Religion	Protestant	778	69.16%
	Orthodox	347	30.84%
	Catholic	-	0.0%
	Muslim	-	0.0%
	Waqeffata	-	0.0%
	Has no religion	-	0.0%
	Others	-	0.0%
	Total	1125	100,00%
Educational level	Illiterate	528	46.93%
	Grade 1-4	210	18.67%
	Grade 5-8	200	17.78%
	Grade 9-12	131	11.64%
	Graduate and above	56	4.98%
	Total	1125	100,00%

is typically used for placental removal and to relieve stomach cramps or abdominal pain in women after childbirth (Additional File 1B). Yesha requires a long maturation period and, once fully matured, is prized for its pleasant taste when consumed. The yam landrace called "Gandifa" in the Basketo area and "Hatseya" in the Daramalo district are the most expensive and highly preferred due to its large tubers, excellent taste, and status as a highly preferred dish for holidays and special guests. Farmers reported that "Gandifa" was inherited by a beloved son and was not managed by women. It is always planted near the home because it requires high soil fertility and intensive farm management. In contrast, other yam landraces can be planted in the field, as they require less management and soil fertility than Gandifa. By continuing to cultivate and exchange these varieties (Table 8 and 9), farmers preserve a wide range of genetic traits often overlooked in commercial agriculture, which tends to favor a limited number of high-yielding varieties. Traditionally, farmers conserve seeds tubers from the best-performing plants for future planting, preserving resilient yam varieties and selecting traits such as drought tolerance or early maturity. These practices enhance diversity and adaptability. Farmers further boost yam production by using genotypes tolerant to low soil fertility, a critical factor for those with limited access to agricultural inputs. Traditional farming methods, deeply rooted in local knowledge systems, enable farmers to employ specific propagation techniques, such as the use of seed tubers, and optimal planting schedules to maximize productivity. Farmers in the Basketo Special Zone, for instance, had a profound understanding of their preferred yam tuber crop, which they cultivate, characterize, and use extensively. Such community attitudes and perceptions contribute to the conservation of various yam landraces, primarily in home gardens and, to a lesser extent, in crop fields. Farmers preserve yam biodiversity by conserving genetic lines on-farm through informal seed banking practices. These efforts serve as a buffer against market pressures and environmental changes. Moreover, these traditional practices, passed down to generations through family and community interactions, oral storytelling and hands-on training, ensure that genetic resources remain intact and well-adapted to local environments. However, key informants reported that the decline in yam production (Figure 2) is mainly due to limited attention and younger farmers shifting to commercially viable alternatives crops khat, coffee, teff, and cassava. Respondents also recalled past rituals such as communal gathering held in Whadha Balansa Kebele of Basketo to celebrate and ceremonially taste the first boiled yam tuber upon its maturity. Yam was once a staple food, a festival dish, a main income source, and a key protein source. However, the study found that yam is now only a supplementary food (Figure 3).

On-farm management practices for yam production

Agronomic inputs and farm managements practices

The agronomic inputs for yam production are presented in Table 4 below. The study revealed that the primary sources of yam seeds were the previous year's harvest (87.91%), followed by purchases from the market (67.29%) and neighbors (29.42%). Nearly all respondents cultivated local yam landraces (99.73%), while only a few (0.27%) grew wild yam land races. Furthermore, approximately 99.73% of farmers did not use agrochemical treatments for yam disease protection (Table 4). Instead, they removed the diseased yam landraces, often losing the entire yam crop for the year due to the unavailability of disease treatments (Additional File 2A). Farmers employed various soil amendment strategies based on their IK (95.02%). These included the use of animal dung (71.29%), a mixture of compost and animal dung (18.93%), yam growing without any amendments (54.84%) and, in rare cases, used chemical fertilizer (0.18%), relying solely on the rainy season (100%) as the only irrigation source for their yam plantations (Table 4).

A lack of guidance from development agents (99.38%) and the scarcity of yam seed supply (96.71%) significantly affected yam production in the study area. Approximately, 96.71% of farmers reported an annual increase in seed costs, which often exceeds their financial capacity to afford (Table 4). The farmers spend more than one (1) USD (100–120 Ethiopian Birr) per yam tuber for seedling propagation, making it increasingly unaffordable. Due to inadequate storage facilities, the farmers prefer to keep yam seeds in the soil until the next plantation seasons. However, the small amount that was buried in the soil was lost due to a prolonged drought (Tables 4 and 5). The study revealed that farmers allocate a significantly higher portion (94.31%) of their farmland to cereals and cash crops, negatively impacting yam production (Table 4). From the total mean agricultural farm size of 0.88 ± 0.86 hectares, only fewer than 0.063 ± 0.07 hectares, on average, was allocated to yam cultivation. Relatively, farmers in Basketo Special Zone and Daramalo districts allocated larger areas to yam farming (0.06–0.13 hectares), whereas farmers in Offa district allocated fewer than 0.012–0.031 hectares. Moreover, women's involvement in yam production is significantly lower (17.87%) compared to that of men (83.56%), youths (49.24%), and daily laborers (41.69%), which may affect overall yam productivity (Table 4). According to respondents, 51.91% reported that most yam landraces are susceptible to diseases and moisture stress, while 48.09% of respondents indicated that some landraces show tolerance (Table 4). Examples of tolerant yam landraces includes: Dortsa, Tolla, Wadala, Ayno, Busuphi, Oha, Ochie, Bune, Aha, and Yesha.

Yam production trends and farmers' preferences of yam production

Previously, about four to six decades ago, yam production was dominant and highly preferred by farmers. However, in recent years, yam production has become rare (Figure 2 and 3; Table 5) and has been replaced by cash crops, cereals, taro (*Colocasia esculenta* L.), potato (*Solanum tuberosum* L.), sweet potato (*Ipomoea batatas* L.), enset (*Ensete ventricosum* (Welw.) Cheesman), and cassava (*Manihot esculenta* Crantz), as reported by farmers. According to respondents, taro and cassava, which were introduced by the Basketo Special Zone's and the Daramalo and Offa districts' agricultural offices to ensure food security, have become a dominant crop and pose a significant threat to yam production (Table 5; Additional file 3). Despite this shift, yam yields remain significantly higher than those of other cereals, cash crops, tuber, and root crops currently being cultivated (Table 5).

The study revealed that 70.93% of farmers have a higher preference for yam production, while a small percentage (2.76%) expressed no preference. However, yam production has shown a decreasing trend over time, with 77.51% of respondents reporting a decline, and only 8.44% noting an increase (Figure 2). This trend can be attributed to various factors, as outlined in Tables 4–6, as well as the Additional File 3. Additionally, respondents agreed that the yam production area covered by their parents was significantly larger, greater than average of 0.30 ± 0.39 hectares, compared to the current yam production farmland, which is markedly smaller, below 0.063 ± 0.07 hectares on average.

Yam production constraints

Yam production in the Basketo Special Zone, and Offa, and Daramalo districts was threatened by various biotic and abiotic environmental factors (Tables 4–7). Key challenges include drought and climate change (97.78%), the labor-intensive nature of yam cultivation (95.29%), the lack of quality seed supply (64.53%), the lack of capacity building training (98.93%), the unavailability of yam staking materials (98.76%), financial constraints (91.64%), land scarcity (96.27%), the lack of a market chain (92%), and access to credit (99.2%), and these significantly affect yam productivity. Among these, wild animal attacks and disease (95.64%; Additional File 2A, B), particularly caused by mole rats and porcupines, frequently lead to the partial or complete destruction of yam farms in the study area (Table 6).

Despite an average annual expenditure of 1000–2500 ETB (approximately USD 20–45) per farmer, 82.22% of respondents reported that their efficiency in purchasing and utilizing agronomic inputs has not improved over time. This was attributed to a lack of financial resources (91.64%) and the high costs of agricultural inputs. Additionally, farmers did not maintain agricultural accounting records, primarily due to a lack of knowledge and the small scale of their transactions (Table 6). The majority of respondents (95.47%) acknowledged that droughts have occurred over the past 10–20 years, primarily affecting cereal crops (64.98%) more than roots, tubers, and other crops. Furthermore, 65.87% of respondents reported the negative impact of disease on yam cultivation (Table 6).

Harvesting and postharvest handling of yam landraces

The study found that, currently, farmers prefer single harvests (53.6%) over double harvests (46.4%) for yam production. This preference may lead to reduced yields and increased post-harvest losses (Table 7). Yam producers face significant storage challenges (84.44%), which contribute to yam post-harvest losses ranging from a quarter of the harvest (55.2%) to the entire harvest (13.96%). Most farmers store their yam products by burying them in the soil (83.2%), while others sometimes store them on house floors (45.5%). Furthermore, 63.2% of producers do not store their yam products at all, and none reported having access to modern storage methods for yam preservation (Table 7). The same issue was report by the "Female Yam Producer Unions" established in the Wadha Balansa kebele of the Basketo Special Zone. In addition to the yam production constraints mentioned under Tables 4-7, the union faces challenges such as the high cost of rented land, 10,000 ETB (approximately USD 100) annually for 0.25 hectares. Other significant issues include high transportation costs (76.89%), fluctuating market prices (99.2%), and the absence (99.91%) of Micro-, Small, and Medium Enterprises (MSMEs) to either prepare yam seedlings for sale or purchase yam products from producers. These challenges severely impact yam production in the study area (Table 7).

Yam landraces diversity, distribution and abundance in the study area

Yam landrace diversity recording

A total of 27 yam landraces (i.e Basketo; 15, Offa; 10 and Daramalo; 2) were recorded across the three districts as indicated in "*".The distribution of yam landraces significantly varied between districts and Kebeles, with most shared among Kebeles due to their proximity. The Basketo was identified as having the highest mean distribution of yam landraces (3.74 ± 1.45), followed by the Daramalo (2.85 ± 0.70) and Offa (2.12 ± 1.21) districts (Table 8). While Wadha Balanssa kebele of Basketo district exhibited the highest mean records of yam landrace (4.03 ±1.65) per farm levels, compared to Kebeles of Daramalo and Offa districts (Table 8). The majority of farmers in Shella, Sassa, Garbeya, Doko, Wadha, and Debtsa Kebeles of Basketo districts had 4(44.07%), 3 (32.14%), 3 (27.27%), and 1 (20%) yam landraces on their farm fields respectively. Farmers in Dara Dime, Menena Abaya, Menena Selo, and Malo Machie Kebeles of Daramalo district 3(57.55%), 3(55.10%), 3(42.86%) and 1(36.67%) while Okotosere, Wazara, Sodaye, and Yakima Kebeles of offa district had 1(49.41%), 2(47.67%), 1(39.42%), and 2(34.18%) yam ladracess respectively per farm level (Table 8). The study found a decline in yam landrace diversity, with only one to three varieties remaining in home gardens, compared to the greater diversity maintained by previous generations (Figures 2-3; Tables 8-9). On-farm visits and key informant reports show that most farmers in Daramalo and Offa districts now grow only a single landrace, such as "Hatseya" or "Wadala."

Abundance and variability of yam landraces

The study found notable variation in the abundance and distribution of yam landraces across Kebeles in each district (Table 9). The higher abundance values, indicates the widespread distribution of yam landraces within each Kebeles and district. Kebeles like Doko Chorie, Wadha, Menena Selo, and Menena Abaya from the Basketo and Daramalo district are areas where higher yam production is practiced (Table 9). The Wadala yam landrace is widespread in Offa district across all Kebeles, while Gandifa, Ayno, and Gebsh are common in Basketo Special Zone. Ayno, Hatseya, and Tolla are prevalent in Daramalo district. Wadala is known for its drought resistance and high yields in the Offa district, whereas Ayno demonstrates tolerance to both drought and disease in Daramalo and Basketo. Gandifa from the Basketo Zone, Hatseya from Darmalo, and Bota and Wadala Boye from the Offa district are highly preferred yam landraces by farmers and fetch premium prices in markets (Table 8 and 9). Farmers also categorized yam landraces into single-harvest such as Afri, Aha, Aykil, Ayno, Bassa, Busuphi, Wadalla, Yesha, Bune, Dortsa, Wolgide, and Tolla, while double-harvest types include Gandifa, Kekila, Hatseya, Gebsh, Duurundufa, Oha, Ochie/Ocha, Welwa, and Katayina. Unique and wild yams such as Yesha, Aha, Wolgide, Busuphi, Ocha, and Oha differ from the others, which are domestic (Table 9). Landraces such as Aha, Kossa, Gassa, Fara, Aykil, Wayicha, Zoremoyire, and Suyitiyia are unique to their respective Kebeles, while the other landraces are shared among the Kebeles within each district (Table 9).

Yam landraces diversity across the study districts

The results indicated a significant mean difference among the study districts and Kebeles in yam landrace richness and diversity ($R^2 = 0.259$, $p < 0.05$; Tables 9-11). The highest yam landrace richness was recorded in the Basketo Special Zone ($R = 75$), followed by Offa ($R = 40$) and Darmalo ($R = 27$) districts (Table 10). A highly diverse yam landrace community was observed in the Basketo Special Zone ($H = 25.9$), followed by the Daramalo ($H = 16.6$) and Offa districts ($H = 16.15$). The Basketo Special Zone also exhibited higher evenness ($E = 10.22$), followed by Daramalo ($E = 8.87$) and Offa ($E = 6.81$) districts (Table 10).

The Simpson's Diversity Index (1 - D) measures diversity by considering both the number of species present and the relative abundances of each yam landrace. This index indicated that the Basketo Special Zone and Offa District had relatively higher abundances of yam landraces (Table 10). On the other hand, the Sorensen Similarity Index (SI), which measures the overlap between two populations by comparing the number of species shared between them to the total number in both populations, ranges from zero (no overlap) to one (perfect overlap). This index showed that all paired sites within each district are closely similar in terms of landrace composition (Table 10). An SI value of less than 0.5 indicates that the paired communities share different species compositions. Conversely, when the value is greater than 0.5, it suggests that the paired communities share similar yam landrace compositions, as observed in the study area of the districts' Kebeles (Table 10).

Yam landraces and conservation

According to the respondents opinion, the conservation status of yams is as follows: threatened (59.38%), very rare (23.2%), and endangered (8.62%) (Figure 3). According to the respondents, yams were previously considered a staple food, and larger areas of farmland were allocated for their sustainable production. However, at present, yams are primarily a supplementary food (87.2%), a seasonal and emergency food (72.89%), a staple food (41.07%), and a food source for poor households (24.53%). This shift is attributed to reduced yields and a decrease in the diversity of yam landraces in farmers' fields, compared to the diversity of yam landraces grown by their parents (Figure 3).

Socio-economic importances of yam landraces

According to the respondents, 37.6% stated that the economic return and profitability from yam production were higher, as yam cultivation yields more (92.18%) and generates more income (48.53%) compared to other crops (Tables 7 and 11). Primarily, yam is produced for tuber consumption (99.47%), which provides a high-nutrient value (92.18%) in the study areas. Yam production offers numerous advantages, including drought resistance (94.31%), availability in the absence of staple food (78.84%), fast growth, and high yield (66.22%) compared to other crops' production (Table 12). Additionally, 92.18% of respondents believe that sustainable yam production can reduce food insecurity and improve malnutrition in marginal and remote communities, while 66.67% believe that saving can help reduce the impact of food insecurity by improving agricultural production (Table 12). Farmers produce yam primarily for their immediate and seasonal household food security (Figure 3), without access to information about food security (95.56%). The availability of yam landraces on the market depends on the production season, a high yield, and a preference for consumption. Yam landraces such as Wadala (31.11%) and Yesha (22.57%) are available and consumed when other types are not available on the market (Table 12), often due to a low preference or high yield availability. Yam landraces like "Gandifa", "Qekila", and "Afri" are highly preferred by farmers for their sweet taste. "Ayno", "Gandifa", and "Duurundufa" produce large tubers, while "Qekila", "Afri", and "Gebsh" are known for their high yield due to their ability to produce many tubers compared to others.

The assessment indicated that yam is expensive, with prices ranging from ETBirr 2500 to 3000 (approximately USD 15–20) per 100 kg, depending on its availability during the production season. However, sales decisions and income ownership are predominantly dominated by men (61.24%), followed by both men and women (24.44%), and women only (5.51%). This reflects the presence of cultural influences and gender inequality (Figure 4). The study clearly indicated that local market prices for yam products were primarily determined by producers (72.44%) and market price information (68.71%). These prices are influenced by availability of yams during the production season and consumer demand (Figure 4).

Table 4: Agronomic inputs for yam production in the study area

Variables	Values	Frequency	Percentage
Sources of yam seeds	Home/previous year's harvest	989	87.91%
	Market	757	67.29%
	Neighbors	331	29.42%
	Wild	19	1.69%
	Government (agricultural office)	-	-
Types of Yam landraces	Local/cultivated	1122	99.73%
	Wild	3	0.27%
	Improved	-	-
	Both improved and local	-	-
	Others	-	-
Yam landraces those are more productive?	Cultivated	1122	99.73%
	Wild	2	0.18%
	Improved	1	0.09%
	Wild and cultivated	-	-
Yam planting methods	Row planting	1070	95.11%
	Yam alone	1037	92.18%
	Intercropped	465	41.33%
	Rotation	394	35.02%
	Randomly	256	22.76%
	Others	-	-
Method of chemical or organic fertilizers applications	Using own indigenous knowledge	1069	95.02%
	Not applied at all	65	5.78%
	Guided by Development Agent's	4	0.36%
Use of agro-chemicals	No agro-chemical applied	1122	99.73%
	Herbicides	3	0.27%
	Insecticides	-	-
	Fungicides	-	-
Fertilizer inputs	Using animal manure only	802	71.29%
	Just grow without any treatment	617	54.84%

to be continued...

Variables	Values	Frequency	Percentage
	Both compost and animal manure	213	18.93%
	Using compost only	95	8.44%
	Using chemical fertilizer only	2	0.18%
Irrigation for yam production	Using rain fed only	1125	100,00%
	Using irrigation only	-	-
	Both irrigation and rain fed	-	-
Access to extension	Yes	1118	99.38%
Services (DA's)	No	7	0.62%
Yam seed scarcity	Yes	1088	96.71%
limit production	No	37	3.29%
Yam seed cost	Higher	1088	96.71%
	Cheap	37	3.29%
Family involvement in yam production	Men only	940	83.56%
	Youths	554	49.24%
	Daily laborer	469	41.69%
	Women only	201	17.87%
	Whole family	136	12.09%
	Others	(helpers)	0.18%
Larger size agricultural land allocation for Yam production	Yes	64	5.69%
	No	1,061	94.31%
Trends of rainfall	Decreasing	865	76.89%
	Increasing	163	14.49%
	Constant	92	8.18%
	Don't know	5	0.44%
Yam landrace more susceptible to diseases and moisture stresses	All	584	51.91%
	Some	441	48.09%
	None	-	-

Notes: percentages exceeding 100% are due to respondents providing multiple entries.

DISCUSSION

The study examines on-farm yam management practices, conservation, production constraints, socio-economic importance, and the indigenous farming knowledge of local farmers. The study revealed that, yam production, conservation, and socio-economic contributions were significantly declined in the study area due to several factors mentioned in Table 4-7 and Figure 2-4. In addition, Ethiopia's reliance on rain-fed agriculture makes it vulnerable to frequent droughts and other natural calamities (Agidew and Singh 2018; CSA 2020; Demilew 2022). To meet the needs of its growing population, Ethiopia requires high-yielding, genetically diverse root and tuber crops, such as yams (CSA 2020). Cereals contributed 49% energy towards global food security while oils (12.5%); meat and eggs (9.5%); sugar (9%); fruits (3%); the contribution of tuber crops like yam is 5.4% (FAO, 2009). Comparison of nutritional composition indicates, energy (322,670, 360, 494), protein (2, 1.4, 1.6, 1.5), lipid (0.09, 0.28, 0.05, 0.17), carbohydrates (17, 38, 20, 28), fiber (2.2, 1.8, 3.0, 4.1), fat (0.07, 0.02, 0.13), sugar (0.78, 1.7, 4.18, 0.5), calcium (12,16, 30,17), and vitamin C (19.7, 20.6, 2.4, 17.1) for potatoes, cassava, sweet potatoes and yams respectively (USDA 2015; Chandrasekara and Kumar 2016). Yam provides; protein (0.6–18.7%), fat (0.30–8.13%), fiber (0.61–18.2%) and ash (0.69–8.81%), depending on yam species (Obidiegwu et al. 2020). Thus, yam crops provide a more diverse and balanced diet, contribute to income generation, serve as traditional medicine, and uphold socio-cultural values (Hildebrand 2002; Pascual et al. 2011; Nweke 2016; Frossard et al. 2017; Wendawek et al. 20021; Demilew 2022). Additionally, yam cultivation creates job opportunities for low-income families (Byerlee et al. 2008; Massawe et al. 2015; Nweke 2016).

The study found major constraints limiting yam production and diversity in Basketo, Daramalo and Offa districts. Farmers in Daramalo and Offa districts cultivate fewer diverse yam landraces despite the Basketo Zone's remarkable diversity (Table 8-10), often sharing common landraces due to geographical proximity, similarity in farming and cultural practices (Wendawek et al. 2021). West Africa's yam genetic resources face similar threats like habitat loss, climate change and the erosion of traditional knowledge, but institutional focus on conservation (ex-situ) and seed system development is stronger (Condé et al. 2025). Yam production in the study area is increasingly neglected as farmers shift to more profitable and less labor-intensive cash crops such as cassava, taro, legumes, and cereals (Muluken et al. 2007; 2008; Belachew et al. 2017; Tizazu 2019). This trend is largely due to the yam production constraints outlined in Tables 4–7. Additionally, the widespread introduction of cassava and taro by district agricultural offices further threatens yam cultivation in the study area (Additional File 3). These crops are preferred due to their tolerance to drought and disease, relatively higher yield (Table 5), year-round availability, compatibility with local conditions, and strong market demand. The unique biological characteristics of cassava, enset, and taro enable them to adapt and perform well (Table 5; Additional File 3) in drought-prone areas (CSA 2020). In Ethiopia, under optimal conditions, cassava can yield up to 80 tons (FAO 2018), while taro and yam yield 26.391 and 9.383 tons per hectare (Table 5), respectively, at the national level (CSA 2020). As a result the genetic diversity of yams is being eroded (Figure 3; Table 8-11) and replaced by improved cultivars or cash crops (Muluneh et al. 2011; Belachew et al. 2017; Baressa and Itefa 2019; Tizazu 2019; Wendawek et al. 2021; Demilew 2022). The distributions of yams are significantly influenced by the cultivation of taro, which is widely grown and commonly practiced by the Sheko people (Belachew et al. 2017). Consequently, the majority of farmers in the Daramalo district have only a single yam landrace such as "Hatseya". The findings align with the report by Tizazu (2019), which states that only a few households in the Daramalo district cultivate yam landraces on shared plots of land with minimal capital investment.

Soil infertility has been identified as a significant factor influencing yam production and diversity, as yam species require fertile soils for optimal growth (Ekanayake and Asiedu 2003; Lebot 2009; Frossard et al. 2017; Matsumoto et al. 2021; Condé et al. 2025). In West Africa, traditional practices involve cultivating yams as the first crop following long-term fallow periods to meet the crop's high soil fertility requirements (Frossard et al. 2017). However, yam farming systems in sub-Saharan Africa are under threat due to a lack of modern technology capable of improving soil fertility, controlling weeds and diseases, and managing pests (Ekanayake and Asiedu 2003). Farmers report that poor soil fertility harms plant health, lowers crop yields, and reduces yam populations, leading to less diversity among yam landraces and greater vulnerability to pests and diseases (Figure 3).

Yam production faces significant challenges, including attacks by wild animals, diseases, and pests that significantly reduce yields and damage plant populations (Tables 4–7; Additional File 2A, B), ultimately leading to selective yam diversity erosion and the dominance of disease-resistant landraces (Additional File 2C). Farmers reported that yam pests, particularly porcupines and mole rats, are common and cause significant tuber damage, which facilitates fungal infections and rot. Similar results were reported in the Jimma, Sheka, and Bench-maji zones of Southwest Ethiopia (Mulualem et al. 2022) and East Wol-

Table 5. Estimated yields of some selected crops (tons/ha).

Crops	Basketo Zone	Daramalo District	Offa District	National Level (2019/2020)	Reference
Teff	0.8	1.6	2.2	1,843	CSA, 2020
Wheat	2.5	4.6	3.6	2,881	CSA, 2020
Barely	2	3.4	2.4	2,184	CSA, 2020
Sorghum	1.8	2	2.91	2,861	CSA, 2020
Maize	4.5	4.7	5.16	4,169	CSA, 2020
Sweet potato	35	45	37.9	36,736	CSA, 2020
Potato	20	52	26.05	14,070	CSA, 2020
Taro (Godere)	25	42	42.97	26,391	CSA, 2020
Yam	35	26	38.8	9,382	CSA, 2020
Cassava	40	32	37.05	80.00	FAO, 2018
Haricot beans (wht)	3.5	2.2	5.16	1,740	CSA, 2021

Source: The yield of different cereals and tuber crops obtained from the three district agricultural offices, 2023. Notes: 1MT = 1,000 kg= 10 quintal.

lega and Ilu Ababora Zones of Ethiopia (Yeshitila and Temesgen 2016). These cumulative pressures have resulted in the erosion of yam landrace diversity, leaving farmers with fewer yam landraces (Table 8) compared to the diversity coverage available to their parents (Belachew et al. 2017; Demilew 2022; Muluken et al. 2008; Tizazu 2019; Mulualem et al. 2020; Wendawek et al. 2021). For instance, medicinal yam landraces such as Ochie/Ocha in the Daramalo district, and Yesha in the Basketo Special Zone, are becoming endangered, as reported by farmers (Additional File 1A, B). Ocha and Oha, which are rare medicinal landraces are highly vulnerable to moisture stress and are found in only a few plots in the Gamo and Wolayta Zones (Wendawek et al. 2021). Busuphy, another rare farmer's landrace, late-maturing, and stress-tolerant, grown only in the Basketo Special Zone. Its limited distribution suggests that this farmers' landrace could easily face local extinction due to being cultivated by only a small number of farmers (Wendawek et al. 2021). The overexploitation of wild yam species with valuable secondary metabolites, such as allantoin and steroidal saponins, further exacerbates conservation concerns (Nweke 2016; Lebot et al. 2019). Additionally, farmers' criteria for selecting landraces based on their resilience to various environmental stress factors limit landrace diversity and distribution across different farms (Wendawek et al. 2021). Most yam landraces are at risk of extinction, owing to their rarity and restricted distribution in Wolayita and Gamo-Gofa (Muluken et al. 2008). Similar challenges have been reported in southern, western, and south-western parts of Ethiopia (Hildebrand 2002; Sebsebe et al. 2003).

Land scarcity (96.27%) and lack of awareness (72.53%) were identified as major constraints affecting yam production and diversity in the study area. Land scarcity directly limits yam cultivation and reduces diversity by restricting the number of yam landraces that farmers can grow (Figure 3; Tables 6, 8-10). Compared to the past (parents), the study found a significant decline in land allocated to yam production, dropping from over 0.30 ± 0.394 hectares to less than 0.07 ± 0.08 hectares on average. Due to high population density and limited farmland, farmers in Offa district allocate less land (0.012–0.031 hectares) to yam cultivation than those in Basketo Special Zone and Daramalo districts. The replacement of yam farms by high-value crops has contributed to land scarcity in Ethiopia (Belachew et al. 2017; Wendawek et al. 2021; Mulualem et al. 2022). Land scarcity is also a real problem in West Africa (Condé et al. 2025). This reduction in land area has resulted in the erosion of yam landrace diversity, as farmers are forced to rely on fewer landraces in their home gardens (Figure 3; Tables 8-10).

The study found that farmers tend to prefer single (53.6%) or double (46.4%) harvests, depending on land availability and family needs (Table 7). Double harvest involves farmers harvesting yam varieties twice in one growing season, while single harvest only harvests yams once (Wendawek et al. 2021). Farmers with surplus land often practice double harvesting to extend production and meet seasonal food gaps, but at the cost of lower quality and yield. Those with less land prefer single harvests, focusing on high-quality tubers, better yields, and crop rotation to meet immediate family needs (Table 9). Similar results were reported by Wendawek et al. (2021). This practice reflects the diverse management strategies that farmers adopt in response to land scarcity. These different harvesting techniques, shaped by available land and resources, indicate a complex system of on-farm management where farmers make decisions based on multiple factors including land size, family needs, and market demand (Figure 2 and 3; Tables 3–7 and 12).

Despite this, the study reveals that yam landraces are highly productive. Farmers harvest an average of 0.576 ± 6.18 tons of yam yield per season from the allocated yam farmland, which is typically less than 0.062 ± 0.07 hectares. The calculations indicate that farmers achieve an annual harvest of 9.216 tons of yam per hectare annually using their local indigenous knowledge (LIK), despite limited farm management, inputs, and other production constraints (Tables 4–7; Additional File 2A, B). This implies that yam yields could be significantly increased through the full implementation of agronomic inputs, disease, and drought-resistant seeds, and improved farm management practices. However, yam production is declining due to reduced yam land coverage, which necessitates urgent attention (Demilew 2022). Ethiopia has significant opportunities to improve yam production sustainably, with more than 15% of arable land under cultivation and more than 60% of cultivated cropland contributing to potential yam production (Demilew 2022). Furthermore, the study also highlights that limited availability and high costs of planting material (98.76%; Tables 4 and 6; Additional File 2C) further compound production, accounting for approximately 50% of the production cost in Africa (Oyetunji et al. 2007). Yam cultivation, which is inherently reliant on staking, requires it for optimal growth (Oyetunji et al. 2007; Muluneh et al. 2008; Viruel et al. 2010; Yeshitila and Temesgen 2016; Belachew et al. 2017; Tizazu 2019; Tsegaye 2021; Wendawek et al. 2021; Mulualem et al. 2022). A simple sequence maker improves dwarf variety breeding efforts for desired yam plant architecture, thereby reducing yam producer farmers' expenses and labor expenditure (Viruel et al. 2010). Moreover, low attention given to the crop, drought during early growth stages, and shortages of stakes and labor exacerbate production issues (Mulualem et al. 2022). Addressing these constraints could unlock the full potential of yam production in Ethiopia.

The lack of modern storage facilities is a significant issue affecting yam production in the study areas, with 84.44% of farmers reporting inadequate storage options (Table 7). This limitation often forces farmers to leave yam tubers buried in the soil, store them temporarily on their home floors, or, in some cases, not store them at all (Table 7). The absence of proper storage facilities has resulted in high post-harvest losses, which can range from a quarter of the harvest to the entire yield, depending on the annual production (Table 7). This issue aligns with findings from southwestern Ethiopia, where storing using indigenous knowledge (Baressa and Itefa 2019) and insufficient storage capacity have negatively impacted yam quality and yield (Zinash 2008; Sahore and Kamenan 2007). Limited storage capacity contributes to significant post-harvest losses, seasonal food shortages, and nutritional deficiency diseases. Yams are typically abundant and inexpensive at harvest but become scarce and expensive later during planting seasons. Effective storage without loss could stabilize supplies, reduce price fluctuations, and encourage farmers (Zinash 2008). Various factors contribute to yam storage losses, including physiological activities (such as sprouting, transpiration, and respiration), mold, rot, bacteriosis, and insect infestations. These issues affect the tubers' composition, leading to a loss of 10–15% after three months and exceeding 50% after six months. Despite these challenges, yam tubers, unlike cassava and sweet potatoes, can be stored at ambient temperatures for up to 4 to 6 months (Zinash 2008). A study conducted to investigate the nutritional properties of yam, Musa (plantains), and cassava during storage found slight changes in yam tubers over a four-week period, while green plantains and cassava remained unaffected only for a week (Sahore and Kamenan 2007). Various methods have been developed to reduce physiological activities and protect tubers from postharvest diseases, including chemicals (for prolonged dormancy), plant extracts (to delaying sprouting), palm wine (to inhibit rotting and sprouting), gamma irradiation (to inhibit sprouting), and cold storage (Zinash 2008). Postharvest hardening is a significant barrier to tuber storage in yam species, but the identification of specific genes has enabled the breeding of varieties with a longer storage life (Demilew 2022). Moreover, the lack of modern storage systems has resulted in crop loss, limited growth potential, and reduced diversity, while modern storage systems may prevent the repeated planting of the same varieties. The inability to store yams without loss further exacerbates food shortages and food insecurity (Zinash 2008). Despite these challenges, yam tubers are relatively resilient and can be stored for up to 4–6 months at ambient temperatures (Zinash 2008), offering a potential solution if proper storage systems are implemented.

Yam-growing communities in the study area face significant constraints, notably the absence of improved varieties (64.53%) and the reliance on local yam landraces (99.73%). The study indicated that the previous year's harvest (87.91%) was the only source

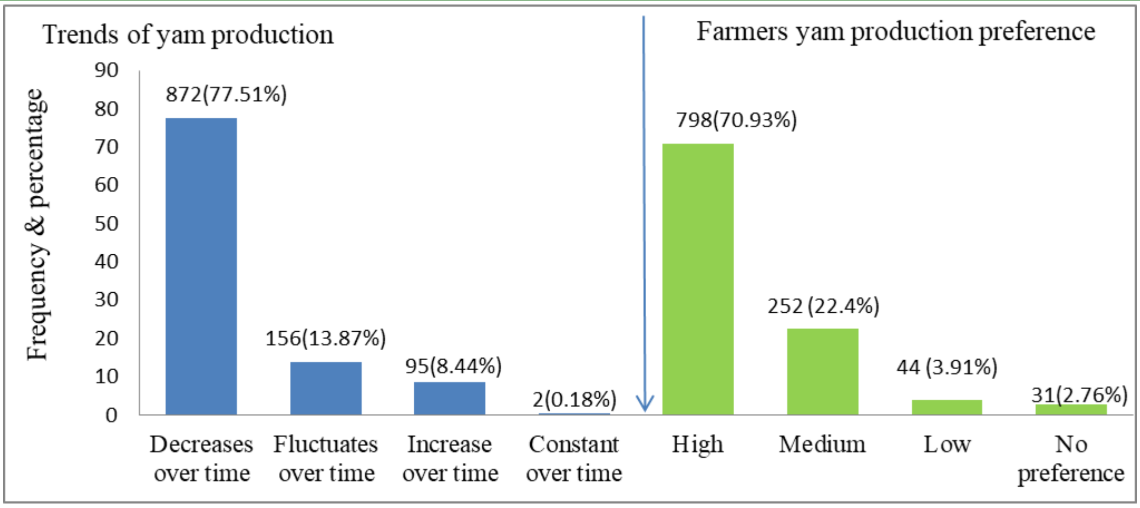


Figure 2. Yam production trends and farmers preference of yam production in the study area.

of seed for farmers (Table 4 and 6). Approximately 99.73% of yam cultivation and propagation in the study area involves the use of local landraces, which limits both distribution and productivity (Figures 2 and 3; Tables 4 and 7). Surprisingly, due to inadequate storage, yam seeds were consumed during a period of starvation, sold for immediate needs, and a small amount remained buried in the soil was lost as result of extended drought (Table 7). According to Oyetunji et al. (2007), farmers need 10,000 seed yams to plant one hectare. If they do not buy new yam seeds, 30% of their harvest must be set aside for planting next year. Additionally, seed yams are bulky and quickly decompose or perish (Oyetunji et al. 2007).Yam production is more expensive than that of other roots and tubers due to its labor-intensive nature and the high costs for planting materials (Oyetunji et al. 2007; Zinash 2008). The main reason for this is that food yams are primarily propagated vegetatively in tropical countries, competing with human consumption and making cultivation expensive for large-scale production (Oyetunji et al. 2007). Traditionally, yams were propagated using whole tubers or large pieces; however, there is a growing trend of using yam minisets or small pieces as planting material (Oyetunji et al. 2007; Zinash 2008). The limited availability of high-quality planting materials hampers large-scale yam production, making low-cost multiplication techniques, such as plant tissue culture, essential for producing uniform, disease-free plants and for screening in vitro stress factors. Traditional vegetative propagation, which involves using 25–100 g pieces of tuber, is inefficient for large-scale seed yam production worldwide (Demilew 2022; Oyetunji et al. 2007). Ethiopia desperately needs methods for mass-producing yam seedlings from seed tubers (Demilew, 2022). In addition, several studies have highlighted the requirement of yam seed producer co-operatives in targeted yam growing areas in Ethiopia (Muluneh et al. 2008; Belachew et al. 2017; Tizazu 2019; Tsegaye 2021; Demilew 2022). However, the study found no micro-, small, and medium-enterprise (MSMEs) associations (99.91%) in the study areas, despite their potential to benefit farmers by making yam seed available and facilitating the purchase of yam products while generating income for themselves (Table 7). Farmers in Ethiopia also have limited exposure and experience with improved yam landraces (Table 4), which negatively impacts the overall yield potential of yams (Bikila et al. 2015; Demilew 2022). The lack of improved and drought-resistant yam varieties could lead to a stagnant genetic pool, with wild yam species being the only survivors in areas without new varieties. Advances in molecular breeding can help to improve yam production by predicting yield potential and developing markers for better tuber quality and yield (Demilew 2022). In 2020, Ethiopia's Ministry of Agriculture reported four yam varieties including Bulcha (*D. alata*) and Lalo (*D. rotundata*) excelling in productivity and disease tolerance, and which are promising for scaling up productivity (Bikila et al. 2015). Despite minimal research on a few and successful varieties, there is limited information and dissemination of improved varieties among farmers (Bikila et al. 2015; Demilew 2022). Ethiopia's southern, southwestern, and western parts have numerous yam species (Muluneh et al. 2007; 2011; Belachew et al. 2017; Wendawek et al. 2021; Mulualem et al. 2022) which can provide a unique opportunity for the development of biotic and abiotic stress-tolerant yam varieties that are well-suited to the environmental conditions (Demilew 2022).

Farmers' yam production practices (on-farm management) are influenced by education status and economic factors. A significant portion (nearly half) of the study population (46.93%) of farmers were illiterate (Table 3), relying on LIK to manage their yam farms, which may limit productivity, market access, value addition, and income generation. For instance, the majority of farmers in the Offa and Daramalo districts cultivate only a single landrace, with minimal investment, primarily for home consumption (Figure 3; Table 8 and 12). Similar results were reported by Tizazu (2019) and Wendawek et al. (2021). Additionally, local feeding habits favoring cereals and other better yielding crops, roots, and tubers (Table 5) compared to yams further diminish their cultivation and productivity (Wendawek et al. 2021; Muluelem et al. 2022). While cassava, enset, and taro thrive under drought-prone conditions, yam yields remain lower at 9.383 tons per hectare nationally (CSA 2021), compared to cassava and taro (Table 5). These dynamics illustrate the complex interplay of cultural, environmental, and economic factors affecting yam management and production.

Farmers employ various traditional soil fertility amendment practices, with 95.02% relying on LIK and a small fraction (0.36%) guided by development agents (DA's) for fertilizer application (Table 4). Soil amendment practices include using animal dung (71.29%), only compost (8.44%), or a combination of both (18.93%), with minimal reliance on chemical fertilizers (0.18%) to improve soil fertility and yam productivity. Rain-fed irrigation (100%) remains the sole water source for yam cultivation (Table 4). To maintain soil fertility for yam productivity, farmers in the Basketo often shift cultivation sites rather than applying fertilizers, which implies that yams requires highly fertility soil for its optimal yield (Ekanayake and Asiedu 2003; Lebot 2009; Frossard et al. 2017; Libot et al. 2019; Matsumoto et al. 2021). In West Africa, declining soil fertility due to continuous cropping without adequate soil management is a significant concern (Frossard et al. 2017). Although applying fertilizers can enhance yam plant growth and yields, the improper use or over-reliance on fertilizers can lead to soil degradation, health issues, and reduced genetic diversity in certain yam varieties that are more susceptible to soil nutrient imbalances. This highlights the need for optimized fertilizer application rates. Additionally, row planting (95.11%) and growing yam alone (92.18%) are preferred for higher yam productivity, though intercropping and crop rotation are common among smallholder farmers, despite the reduced yields associated with these practices (Table 4). The absence of agro-chemicals (99.73%) increases vulnerability to pests and diseases (Mulualem et al. 2022), threatening yam landrace yields and diversity (Figure 3; Tables 4 and 8–11). Farmers may rely on a limited number of disease-resistant yam landraces, further highlighting the potential risks to yam production.

Table 6. Yam production and product related constraints in the study area.

Yam production related constraints	Values	Frequency	Percentage
Yam stacking expenditures		1,111	98.76%
Wild animal attacks and diseases		1,076	95.64%
Accessibility of workers and government strategies		763	67.82%
Lack of capacity building training		721	98.93%
Agricultural research and extension service		585	52.00%
Labor cost		827	73.51%
Drought/climate change		1,100	97.78%
Land scarcity		1,083	96.27%
Lack of awareness		816	72.53%
Quality seed source/improved		726	64.53%
Tediousness of the practice		1,072	95.29%
Scarcity of mother yam		1,076	95.64%
Lack of new technology		770	68.44%
Financial shortage/production cost		989	87.91%
Lack of market chain		1,035	92,00%
Shortage of money for yam production	Yes	1,031	91.64%
	No	94	8.36%
Access to credit facilities	Yes	50	4.44%
	No	1,075	95.56%
Using purchased agronomic inputs for your Yam production improvement	Yes	397	35.29%
	No	728	64.71%
Efficiency of utilization of agronomic input improved over time	Yes	200	17.78%
	No	925	82.22%
Did you have a saving account?	Yes	314	27.91%
	No	811	72.09%
Did you keep accounting records of your agricultural activity?	Yes	441	39.2%
	No	683	60.71%
Purpose of keeping agricultural accounting records	For tax purposes	277	24.42%
	To assess the profit	259	23.02%
	For loan repayment	11	0.98%
	Others	-	-
Reason for not keeping agricultural account recordings	Transaction is too small	551	48.9%
	Lack of knowledge	552	48.98%
	Lack of education	441	41.87%
	Others	-	-
Drought occurrence for the last ten to twenty years	Yes	1,074	95.47%
	No	51	4,54%
Crop more affected by drought occurrence for the last ten to twenty years	Cereal crops (maize, teff,. Etc)	731	64.98%
	Tubers (e.g yam, Taro...etc)	395	35.11%
Have you ever been observed Yam disease in your area?	Yes	741	65.87%
	No	384	34.13

Notes: percentages exceeding 100% are due to respondents providing multiple entries.

Table 7. Yam storage and post-harvest loss.

Variable	Values	Frequency	Percentage
Types of yam harvest preferred by farmers' in the study area	single	603	53.6%
	double	522	46.4%
Yam product storage places	Leaving in the soil (burred)	936	83.2%
	Not stored at all	711	63.2%
	On the floor of home	512	45.51%
	At home, shelf in the house	62	5.51%
	Modern storage	-	-
	Heaps in the field	-	-
	Other ways of storing	-	-
Lack of storage affect yam production	Yes	850	84.44%
	No	175	15.16%
Pre-harvest loss		745	66.22%
Post-harvest loss		847	75.29%
Amount of yam post-harvest loss	Quarter of the harvest	621	55.2%
	Half of the harvest	345	30.67%
	The whole harvest	157	13.96%
	Other (not stored at all)	2	0.18%
Presence of MSMEs or other cooperatives	Yes	1	0.09%
	No	1,124	99.91%
Transport cost	-	865	76.89%
Low prices of the products	-	597	53.07%
Fluctuation(uncertainties) of market price affect yam production	Yes	1,116	99.2%
	No	9	0.8%

Notes: percentages exceeding 100% are due to respondents providing multiple entries.

Table 8. Recorded yam landraces per districts and Kebeles' at the study area

Districts	Kebeles	N	Landraces recorded per kebeles	NLK	(Mean +SD)	LIF	NF (%)
Basketo	Wadha Balanssa	102	1.Gandifa* 6. Duurundufa* 2. Gebsh* 7. Qekila* 3. Ayno 8. Katayina* 4. Afri * 9. Dortsa* 5.Busuphi* 10.Wolgide*	10(13.3%)	4.03±1.6e	1	5(4.90%)
						2	10(9.80%)
						3	24(23.53%)
						4	25(24.51%)
						5	20(19.61%)
						6	10(9.80%)
						7	6(5.88%)
						9	2(1.96%)
	Sassa Malkesa	56	1. Gandifa 8. Qekila 2. Ayno 9. Duurundufa 3. Dortsa 10. Katayina 4. Yesha* 11. Hatsiya 5.Gebsh 12. Golla 6. Wolgide* 13. Kossa* 7. Afri 14. Beza*	14(18.7%)	3.49±1.3cd	1	2(3.57%)
						2	11(19.64%)
						3	18(32.14%)
						4	9(16.07%)
						5	11(19.64%)
						6	3(5.36%)
						7	2(3.57%)
	Doko Chorie	55	1. Gebsh 6. Duurundufa 2. Ayno 7. Afri 3. Gandifa 8. Hatseya 4. Qekila 9. Wolgide 5. Yesha 10. Katayina	10(13.3%)	3.88±1.2de	1	2(3.64%)
						2	5(9.09%)
						3	15(27.27%)
						4	14(25.45%)
						5	14(25.45%)
						6	5(9.09%)

to be continued...

Districts	Kebeles	N	Landraces recorded per kebeles	NLK	(Mean +SD)	LIF	NF (%)
Basketo	Debtsa Dalkinsa	79	1. Duurundufa 10. Ayno 2. Woligida 11. Aha* 3. Gandifa 12. Bune 4. Yesha 13. Afri 5. Qekila 14. Beza 6. Dortsa 15. Aykil* 7. Gebsh 16. Bassa* 8. Bussuphi 9. Katayina	16(21.3%)	3.18±1.9e	1 2 3 4 5 6 7 8	6(7.59%) 9(11.39%) 18(22.78%) 17(21.52%) 6(7.59%) 10(12.66%) 8(10.13%) 5(6.33%)
	Garbeya	25	1. Duurundufa 7. Golla 2. Gandifa 8.Gebsh 3. Hatsiya 9. Ayno 4. Katayina 10.Dortsa 5.Qekila 11.Afri 6.Busuphi	11(14.7%)	3.33±1.4c	1 2 3 4 5	5(20%) 3(12%) 4(16%) 8(32%) 5(20%)
	Shella Kanibolla	59	1. Gebsh 8. Duurundufa 2.Yesha 9. Ayno 3. Bassa 10. Qekila 4. Afri 11. Gandifa 5. Doritsa 12. Hatsiya 6. Wolgide 13. Aykil 7.Busuphi 14. Katayina	14(18.7%)	3.51±1.1cd	1 2 3 4 5 6 7	1(1.69%) 8(13.56%) 19(32.20%) 26(44.07%) 2(3.39%) 1(1.69%) 2(3.39%)
	Mean	**376**		**75(52.5%)**	**3.74±1.45**	**-**	
Daramalo	Dara Dime	139	1. Ayno/Ayna 5. Tolla* 2.Hatseya 6. Wadala 3. Ocha* 7. Bolla 4. Bune 8. Oha	8(29.6%)	2.91±0.6bc	1 2 3 4 5	24(17.27%) 17(12.23%) 80(57.55%) 12(8.63%) 6(4.32%)

to be continued...

Districts	Kebeles	N	Landraces recorded per kebeles	NLK	(Mean +SD)	LIF	NF (%)
	Malo Machie	60	1.Hatsiya 4. Bune 2. Ayno 5. Oha 3. Tolla	5(18.5%)	2.80±0.5b	1 2 3 4 5	22(36.67%) 11(18.33%) 22(36.67%) 3(5.00%) 2(3.33%)
	Menena Abaya	98	1. Ayno/Ayna 5.Ocha 2. Hatseya 6.Oha 3.Tolla 7.Wadala 4. Bune	7(25.9%)	3.01±0.7bc	1 2 3 4 5 6	14(14.29%) 21(21.43%) 54(55.10%) 4(4.08%) 3(3.06%) 2(2.04%)
	Menena Selo	98	1.Tolla 5. Bune 2.Ayno 6. Oha 3.Hatseya 7. Ocha 4.Bolla	7(25.9%)	2.66±0.8ab	1 2 3 4 5	22(22.45%) 26(26.53%) 42(42.86%) 6(6.12%) 2(2.04%)
	Mean	**395**		**27(19%)**	**2.85±0.7**	**-**	
Offa	Waraza	86	1.Wadala 6. Fara 2.Naba* 7. Ayno/Ayna 3.Hatseya 8. Bolla 4.Genna* 9.Gassa* 5.Bune	9(22.5%)	2.30±1.5ab	1 2 3 4	21(24.42%) 41(47.67%) 11(12.79%) 13(15.12%)
	Yakima	79	1.Hatseya 5. Naba 2.Wadala 6. Bune 3.Arkiya* 7.Oha 4.Genna	7(17.5%)	2.15±1.1a	1 2 3 4 5	26(32.91%) 27(34.18%) 17(21.52%) 8(10.13%) 1(1.27%)

to be continued...

Districts	Kebeles	N	Landraces recorded per kebeles	NLK	(Mean +SD)	LIF	NF (%)
	Okoto Sere	85	1.Wadala 6.Naba 2. Hatsiya 7.Genna 3.Oha 8.Bune 4.Zo'omacha* 9.Bolla 5.Welawa* 10.Ayno	10(25 %)	1.88±1.1a	1 2 3 4 5	42(49.41%) 26(30.59%) 10(11.76%) 4(4.71%) 3(3.53%)
	Sadoye	104	1.Ayno 8.Bune 2.Wadala 9.Oha 3.Naba 10.Bota 4 Zorewoyire* 11.Hataiya 5.Fara* 12. Suyitiyia* 6.Wayicha* 13.Arkiya* 7. Welawa 14. Genna	14(35%)	2.14±1.1a	1 2 3 4	41(39.42%) 27(25.96%) 16(15.38%) 20(19.23%)
	Total	**1125**		**40(28.2%)**	**2.12±1.21**	**-**	

Notes: N = number of household responded, NLK=number of yam landraces per Kebeles,SD = standard deviation, LIF = yam landraces numbers ranges per individual farms, NF= number of farmers, Means with the same letters are insignificant at $p < 0.05$.

Effective yam on-farm management is essential to mitigate post-harvest losses. Farmers can adopt practical alternatives of proper harvesting techniques, such as using sharp tools, digging carefully, proper cleaning and drying, and harvesting at the right maturity are necessary to prevent damage to the tubers and to reduce moisture and minimize spoilage. Furthermore, post-harvest treatments, including sprout inhibitors, fungicides, and suitable packaging, can preserve the quality of yam tubers in the study area. On the other hand, to overcome the limitations of local yam varieties, enhancing research investment in breeding programs is highly essential (Demilew 2022). Improved yam varieties *D. alata* and *D. rotundata* have shown potential in increasing productivity and disease tolerance (Bikila et al. 2015). However, in Ethiopia, research investment in the development and release of farmer-preferred yam varieties with tolerance to low soil fertility, disease and drought is still slow compared to the country's demands (Bikila et al. 2015; Demilew 2022). In Nigeria, *Guinea* genotypes thrive under limited soil nutrients and mineral fertilizers (Matsumoto et al. 2021), and similar varieties could be beneficial for Ethiopian farmers facing agricultural input constraints. For successful yam production, a comprehensive approach that includes optimizing seed tuber production, optimizing and applying fertilizer efficiently, land preparation, pest management, effective planting methods, and proper harvesting and storage techniques, as well as viable marketing, are necessary (Demilew 2022).

Local indigenous knowledge (LIK) plays a vital role in the management and cultivation of yam in Ethiopia (Hildebrand 2002; Sebsebe et al. 2003; Wendawek et al. 2021). LIK plays a critical role in yam cultivation, especially among illiterate farmers who constitute nearly half of the study population (46.93%) (Table 3). This knowledge includes traditional farming techniques and cultural practices that sustain yam production in the face of numerous challenges. However, the reliance on indigenous practices, coupled with limited formal education and resources, restricts opportunities for modernization and commercialization. The study found that the farmers predominantly (95.02%) used their LIK in yam cultivation, including soil fertility management, selection of disease and drought tolerant yam varieties, planting techniques, conservation strategies, and developing strategies to overcome the effect of other environmental stressors. According to (Mulualem et al. 2022), farmers prefer yam traits with high yielding (35.42%), good marketability (11.05%), early maturity (8.86%), powdery texture after boiling (10.48%), drought and disease resistance (3.53%), and medicinal uses (5.58%). These preferences underscore the importance of considering LIK in breeding and conservation efforts (Mulualem et al. 2022). Farmers use their LIK to preserve agro-biodiversity, maintain resilience to environmental stresses, and adapt to climate change challenges (Hildebrand 2002; Sebsebe et al. 2003; Muluneh et al. 2008; Wendawek et al. 2021). Traditional farming methods, like shifting cultivation and selective propagation, conserve rare landraces, ensure sustainability, and preserve cultural heritage, highlighting the interconnectedness of farming systems and LIK in addressing global biodiversity challenges. These techniques, however, often occur in the absence of modern farming inputs and formal capacity building training (98.93%) on yam farming (Table 6). Despite limited agronomic inputs, farmers still manage to achieve yields of up to 9.216 tons per hectare annually. The result aligned with (CSA 2021) reports (Table 5). This suggests that there is potential for significantly higher yields if modern farming practices and inputs were implemented (Demilew 2022). LIK is crucial in the ongoing management of yam production, enhancing resilience to environmental stresses, preserving agro-biodiversity, and transferring LIK, particularly in the face of changing climates and global biodiversity challenges. However, the study highlights the need for greater capacity building, promotion and access to resources to help farmers improve their practices and increase productivity in the face of growing challenges. Similarly, Condé et al. (2025) reported erosion of LIK in West Africa.

Traditional farming practices also play an essential role in yam cultivation, particularly in the management of storage and seed preservation. Farmers can adopt practical alternatives to reduce post-harvest losses by utilizing cool, dry sheds and sand storage or well-ventilated pits to extend the shelf life of yams products. In addition, traditionally, yam propagation utilized vegetative methods like whole tubers or large pieces (Oyetunji et al. 2007). However, this practice remains insufficient for large-scale production, necessitating modern techniques, such as tissue culture, to enhance seed yam production. Farmers also rely on their LIK to identify the best planting materials and preserve the tubers for the next season. Farmers' deep understanding of local yam varieties and their cultivation practices have sustained yam farming for generations (Hildebrand 2002; Sebsebe et al. 2003; Wendawek et al. 2021). However, the introduction of improved varieties and modern agricultural practices could enhance productivity (Demilew 2022). While there is a lack of exposure to these improvements among many farmers, bridging this gap with appropriate training and information dissemination could provide significant benefits. By combining LIK with new technologies, Ethiopian farmers can overcome the challenges of yam production and contribute to food security and economic growth. Incorporating farmers' knowledge

Table 9. Yam landraces abundance and variability in the study area per Kebeles

Landraces	Yam landraces abundace per Kebeles													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Gandifa^{d}	53	30	29	38	6	28	0	0	0	0	0	0	0	0
Duurundufa^{d}	47	30	37	49	8	41	0	0	0	0	0	0	0	0
Ayno/Ayna^{s}	70	40	41	65	19	52	108	39	86	83	0	0	0	1
Qekila^{d}	66	34	26	34	15	11	0	0	0	0	0	0	0	0
Afri^{d}	18	1	11	38	7	7	0	0	0	0	0	0	0	0
Gebsh^{d}	63	36	43	57	13	45	0	0	0	0	0	0	0	0
Yesha^{s,w}	0	6	7	6	0	4	0	0	0	0	0	0	0	0
Ahas^{s,w,u}	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Wolgide^{s,w}	5	1	1	8	0	1	0	0	0	0	0	0	0	0
Katayina^{d}	16	1	3	6	1	1	0	0	0	0	0	0	0	0
Doritsa^{s}	7	2	0	0	1	1	0	0	0	0	0	0	0	0
Beza^{s}	0	1	0	1	0	0	0	0	0	0	0	0	0	0
Bune^{s}	0	0	0	1	0	0	8	3	2	6	0	9	10	26
Busuphi^{s,w}	1	0	0	1	1	1	0	0	0	0	0	0	0	0
Bassa^{s}	0	0	0	1	0	1	0	0	0	0	0	0	0	0
Kossa^{s}	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Aykil^{s}	0	0	0	1	0	1	0	0	0	0	0	0	0	0
Hatseya^{d}	0	1	1	0	2	1	120	48	92	87	43	28	75	57
Golla^{s}	0	1	0	0	1	0	0	0	0	0	0	0	0	0
Wadala^{s}	0	0	0	0	0	0	1	0	11	0	73	56	74	87
Tolla^{s}	0	0	0	0	0	0	88	36	45	52	0	0	0	0
Bolla^{d}	0	0	0	0	0	0	3	0	0	3	11	0	4	4
Ocha^{d,w}	0	0	0	0	0	0	3	3	5	5	0	0	0	0
Oha^{d,w}	0	0	0	0	0	0	3	0	4	0	0	5	1	1
Naba^{d}	0	0	0	0	0	0	0	0	0	0	5	15	10	35
Genna^{d}	0	0	0	0	0	0	0	0	0	0	1	6	1	0
Fara^{d,u}	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Gassa^{d,u}	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Arkiya^{d}	0	0	0	0	0	0	0	0	0	0	0	3	0	1
Zo,omacha^{d}	0	0	0	0	0	0	0	0	0	0	0	0	5	1
Welawa^{d}	0	0	0	0	0	0	0	0	0	0	0	0	14	2
Suyitiyia^{d}	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Zoremoyire^{s,u}	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Wayicha^{s,u}	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Notes:1=Wadha Balanssa, 2= Sassa Malkesa, 3=Doko Chorie, 4=Debtsa Dalkinsa, 5= Garbeya, 6=Shella Kanibolla, 7=Dara Dime, 8=Malo Machie, 9=Menena Abaya, 10=Menena Selo, 11=Waraza, 12=Yakima, 13=Okoto Sere, 14=Sadoye Kebeles. d=double-harvest, s=single-harvest, u=unique landraces, w=wild landrace.

into research and development efforts will ensure that new practices are both practical and culturally relevant.

The study revealed a concerning decline in the diversity of yam landraces (Figure 3), which are frequently cultivated on marginal land or shared plots (Tizazu 2019). In the study area, yam landraces are at risk, with 59.38% of respondents reported as threatened and 8.62% reported as endangered (Figure 3). This trend is exacerbated by the dominance of cassava and taro, which are replacing yams due to their adaptability and higher productivity (Table 5;

Table 10. Yam landraces richness, evenness, and diversity in the study districts and Kebeles

Districts	Kebeles'	R	H'	E	1_D	SI-paired values		Ranks
Basketo Special Zone	Debtsa Dalkinsa (I)	16	4481	1.62	989	I Vs II	0.54	1
	Doko Chorie (II)	10	4045	1.76	984			
	Garbeya (III)	11	4345	1.81	954	III Vs V	0.62	
	Sassa Malkesa (IV)	14	4093	1.51	983			
	Shella Kanibolla (VI)	14	4096	1.55	984	VI Vs VII	0.58	
	Wadha Balanssa (VII)	10	4529	1.97	991			
	Total	75	25.9	10.22	5.88			
Daramalo district	Dara Dime (I)	8	4388	2.11	948	I Vs II	0.77	2
	Malo Machie (II)	5	3657	2.27	984			
	Menena Abaya (III)	7	4168	2.14	990	III Vs V	0.86	
	Menena Selo (V)	7	4391	2.26	993			
	Total	27	16.6	8.78	3.91			
Offa district	Okoto Sere (I)	10	4007	1.52	989	I Vs II	0.61	3
	Sadoye (II)	14	4113	1.40	982			
	Waraza (III)	9	4030	1.83	971	III Vs V	0.63	
	Yakima (V)	7	4001	2.06	990			
	Total	40	16.15	6.81	3.93			

SI = Sorenson similarity index, H' = Shannon diversity index, 1 - D = Simpson's diversity index, R = richness, E = evenness (evenness: closer to 1 means a more even community, which implies greater diversity, and closer to zero means a less even community and a less diverse community).

Table 11. Tests' between subject effects and multiple comparisons of landraces per Kebeles

Dependent Variable: Abundance across all district					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	583.941[a]	13	44.919	31.179	.000
Intercept	8476.712	1	8476.712	5883.951	.000
Kebeles	583.941*	13	44.919	31.179	.000
Error	1600.562	1,111	1.441		
Total	11994.000	1,125			

[a] R Squared = 0.267 (Adjusted R Squared = 0.259), * indicates significance difference set at $p < 0.05$.

Additional File 3). Similar result was reported by Belachew et al. (2017) in Sheko, Ethiopia. Yams continue to be displaced and their genetic resources face the risk of extinction, emphasizing the need for conservation efforts (Belachew et al. 2017; Wendawek et al. 2021; Mulualem et al. 2022). Another, key driving factors in this decline are factors mentioned in Tables 4–9, which has initiated a need for conservation strategies to preserve the diversity of yam landraces, particularly by considering the importance of geographical distribution range in Ethiopia. The study highlighted that an elevation range of 1350–2200 m (Table 1) is ideal for yam distribution, production and conservation in Ethiopia, where the crop thrives in open canopy environments, ranging from 1400–1750 m (Subba et al. 2023), 1350-2200m (Muluneh et al. 2011), low (1300-1500m), mid (1500-1800m) and high (1800-2300m) altitudinal ranges (Wendawek et al. 2021) in Ethiopia. These findings underscore the urgent need for targeted conservation in mid to high-altitude areas, where yam

Table 12. Economic return and consumption of yam landraces in the study area

Variable	Values	Frequency	Percentage
Parts of Yam is used/consumed	Tubers	1114	99.02%
	Green pod	11	0.98%
	Leaves	-	-
	Others	-	-
Economic return and profitability of yam production	High	423	37.6%
	Less	374	33.24%
	Medium	236	20.98%
Yam production yields higher income & profitable compared to other crops	Yes	1037	92.18%
	No	88	7.82%
Purpose of yam production	Consumption	1119	99.47%
	Market/income generation	546	48.53%
	Medicinal	111	9.87%
	Cultural uses	48	4.27%
	Animal feed	4	0.36%
	Alcoholic beverage	-	-
	Others	-	-
Nutritional value of yam	High	1037	92.18%
	Less	88	7.82%
Advantages of yam production Compared to other crops productions	Drought resistance	1061	94.31%
	Used in the absence of staple food	887	78.84%
	Grow fast and has high yield	745	66.22%
	Available at any season	16	1.42%
	Require low fertilizer input	-	-
Sustainable yam production/ yield help to reduce the effects of food insecurity	Yes	1037	92.18%
	No	882	7.82%
Presence of saving help to reduce the effects of food insecurity	Yes	750	66.67%
	No	375	33.33%
Access to information on food security	No	1075	95.56%
	Yes	50	4.44%
Yam landrace available and consumed when other types are not available in the market	Yesha	254	22.57%
	Wadala	350	31.11
	Tolla	216	19.2
	Ayno & Bune	119	10.57
	Ochie & Oha	67	5.96
	Kaanatusa & Wolgedie	21	1.87
	Gandifa/Hatseya	55	5.88

production is most viable. A comprehensive strategy is vital to protect yam diversity and ensure the survival

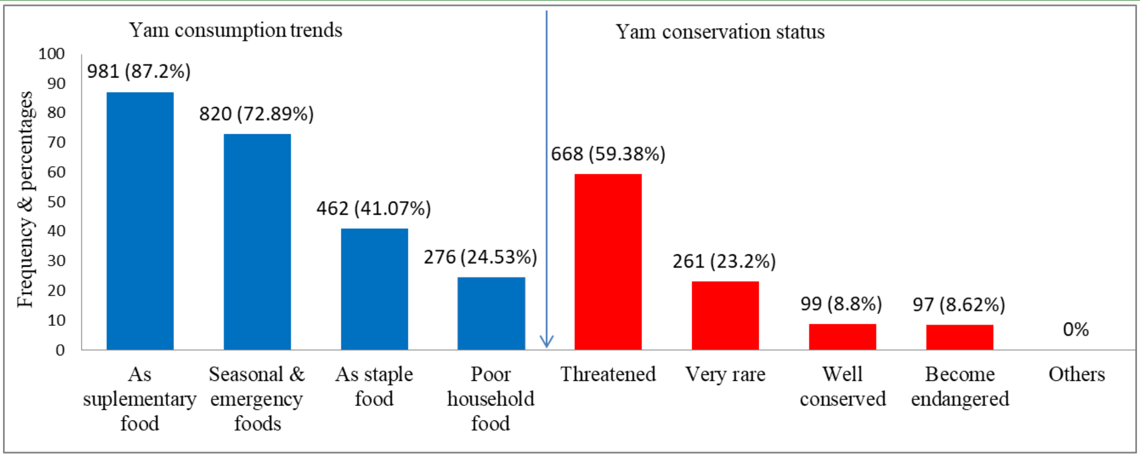


Figure 3. Yam consumption trends and consevation status in the study area.

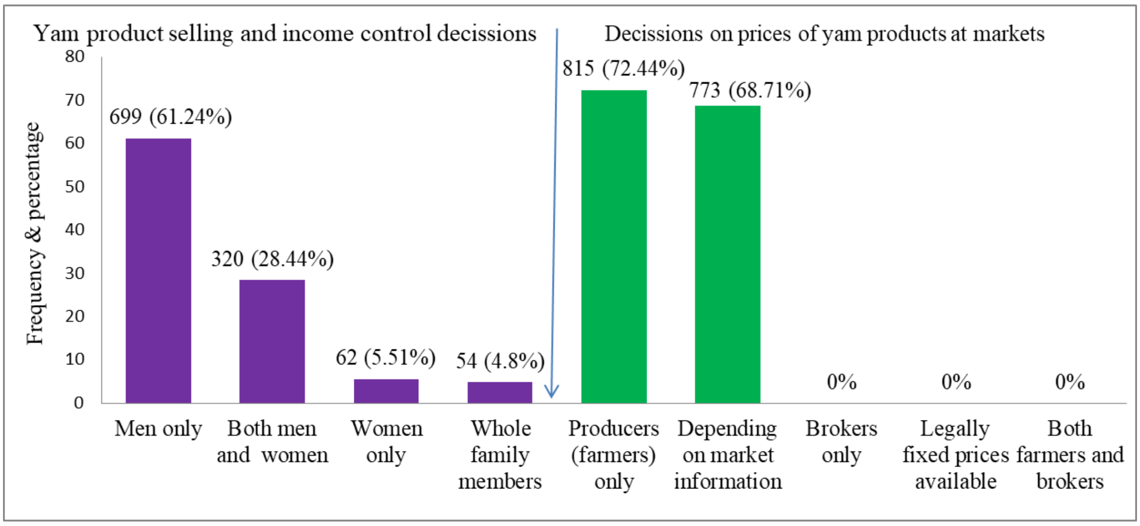


Figure 4. Yam product local market prices, selling decision and income ownership.

of its landraces.

The conservation status of yam landraces was threatened by the inadequate storage systems which limited diversity. The traditional practice of using the previous year's harvest (Table 4) for seed yams results in a loss of diversity (Figure 3; Tables 8–10), making yam crops more susceptible to diseases and pests (Table 6 and 7). The lack of access to high-quality seeds means that farmers rely heavily on what remains from the previous harvest, increasing the risk of crop failure, particularly during periods of drought. Therefore, limited storage capacity prevents the preservation of yam varieties contributing to a reduction in available genetic resources. Continued research to identify yam genes related to disease resistance and tuber quality (Demilew 2022) is essential for the conservation of yam landraces while ensuring food security in the future. Recently, yam production has been declining leading to local extinction attributed to less attention given at local, regional, and national levels (Wendawek et al. 2021; Mulualem et al. 2022). To address this decline, it is essential to implement a conservation and management plans that includes incentive schemes for conservation, establishing field gene banks and creating specialized gardens, promoting yam tuber crops as a crucial food source, maintaining databases, conducting comprehensive studies on yam's genomic and morphological characteristics, disseminating yam-related information would support the conservation efforts and help revitalize yam production in Ethiopia (Wendawek et al. 2021).

Despite the decline in production and diversity, yam remains a valuable crop for food security and livelihoods (Table 12), particularly in densely populated and topographically challenging regions such as the present study area (Table 3). The study found that 50.58% of respondents were aged between 36 and 50, with a mean age of 42.69 ± 10.41, indicating that most households in the study area are in productive stages. The sustainable production and importance of yam are underscored by the active involvement of married households (91.64%), who contribute more labor and resources to its cultivation compared to single individuals with smaller labor forces, limited resources, and less social support (Table 3). Leveraging this demographic advantage could enhance yam production, improve livelihoods, and ensure food security in the region. However, the crop's economic potential remains underutilized due to low market access and limited value addition. Farmers are motivated to grow yams because of their high market price, disease resistance, and ability to thrive in less fertile soils, but these advantages are overshadowed by competition from other root crops and cereals cereals (Belachew et al. 2017; CSA 2021; Demilew 2022; Mulualem et al. 2022; Tizazu 2019).

Yams hold substantial socio-economic value, particularly for smallholder farmers who rely on them for food security, medicine, and income (Muluneh et al. 2011; Massawe et al. 2015; Nweke 2016; Frossard et al. 2017; Wendawek et al. 2021). The diversity of yam landraces in the Basketo Special Zone (Tables 8-10) reflects farmers' adaptation to environmental challenges and their cultural preferences for food security (Table 12). Yams are integral to local diets and cultural practices, often used in traditional ceremonies and are a source of income for rural households (Frossad et al. 2017). Despite their importance, yams receive less attention compared to other staple crops, affecting their development and conservation in Ethiopia (Mulualem et al. 2002). Most smallholder farmers primarily grow yam for consumption (99.47%) rather than for income generation (48.53%) or other purposes (Figure 4; Table 12). This shift in use reflects the changing economic value of yam, as it increasingly becomes more of a supplementary or emergency food rather than a staple (Table 12). Despite its declining role in the market (Table 7), yam continues to play a critical role in household food security in rural areas where access to other sources of income is limited. Smallholder farmers' access to markets for higher-value agricultural products is considered as a crucial opportunity to enhance and diversify the livelihoods of lower-income farming households, thereby reducing rural poverty (Byerlee et al. 2008). Credit barriers, particularly the inability to access loans for farming improvements (95.56%), hinder farmers' from investing in better yam farming practices. This often leads to a reliance on less diverse varieties, limited access to improved seeds, and a lack of modern farming tools (Table 4). These challenges, adversely affect the profitability of yam cultivation and its broader economic potential. As a result, yam, which was once considered a staple food, is now primarily used as supplementary food, seasonal and emergency food, and poor households' food (Figure 3). Addressing these constraints could help increase the income potential of smallholder yam farmers and improve their livelihoods.

Another factor which affects yam production is that, yam cultivation is primarily practiced by men (83.56%), while women are mostly responsible for food preparation and childcare (Table 4). Additionally, decisions regarding yam yield sales and income control are predominantly made by men (Figure 4). In the Jimma, Sheka, and Bench-Maji regions of western Ethiopia, yam production is largely managed by men (75.83%) (Mulualem et al. 2022). This division of labor is often influenced by cultural values and previous land ownership systems, which have historically favored men (Muluneh et al. 2011; Petros et al. 2018). Similar findings have been reported in southern Ethiopia (Tizazu 2019). However, women play significant roles; they are actively involved in storing and cultivating seeds, ensuring that sufficient yams are available for both consumption and planting in the subsequent season (Petros et al. 2018; Mulualem et al. 2022). Therefore, field extension officers should employ communication strategies that consider age, education, occupation, and household size to enhance women and youth participation in yam production. This approach would help improve household food security and the economic well-being of farming families (Petros et al. 2018). For households with an average size of 6.37 members (Table 3), engaging all family members in yam production can increase efficiency and ensure food availability, thereby enhancing family-level food security. In Ethiopia, yam cultivation plays a significant role in the socio-economic fabric, particularly in the southern, southwestern, and western regions, which are rich in yam diversity (Muluneh et al. 2011; Mulualem et al. 2022; Wendawek et al. 2021; Demilew 2022). These diverse landraces hold promise for boosting yam production through the application of improved farming strategies; including efficient seed tuber production and establishing market chain (92%; Table 4) to encourage yam producer farmers. However, the potential of yam cultivation to significantly contribute to the economy may remain underutilized without adequate support. This includes investments in research and the development of improved yam varieties (Demilew 2022).

In summary, the study highlights that yam production and diversity face numerous constraints, leading to a decline in their conservation status, yields, and socio-economic importance. The socio-economic challenges, particularly limited access to market chains and financial constraints, are crucial factors that must be addressed to ensure yam production continues to contribute to food security and livelihoods in rural communities. Conserving yam diversity and integrating IK with modern farming practices are essential to sustaining yam production and realize its socio-economic benefits in the study area. Improving management practices, access to quality seeds, agronomic input, and modern storage solutions could improve sustainability and productivity. Addressing production constraints, improving on-farm management practices, maintaining the socio-economic significance of yam, and ensuring the conservation of yam landraces through research and local engagement are vital steps to revitalize yam cultivation in Ethiopia.

STRENGTH AND LIMITATION OF THE STUDY

This study has a notable strength in that the data collection was conducted using the Kobo Tool software, which included GPS points for each surveyed household. This approach effectively mitigated any potential data collection bias. The software also analyzed the data and generated reports. Prior to data collection, training sessions were conducted for data collectors (DAs) on the Kobo Tool software management and data collection methods to minimize bias in both the data collection and interpretation. A larger sample size (1125 households) from three districts was included, ensuring an accurate representation of the broader population within the study area. The study acknowledges that LIK and practices evolve over time, and the findings reflect the current state and long-term trends. The study combines qualitative methods (e.g., interviews, focus groups) with quantitative approaches to triangulate data. This comprehensive approach enables a holistic understanding of yam production constraints, on-farm management, LIK, conservation status, and the socio-economic significance of sustainable yam production. However, it is important to recognize that the limited sample area (three districts) may not capture the full variability in yam production practices, LIK, socio-economic conditions, or conservation status across Ethiopia. Additionally, LIK is often transmitted orally, with no well-documented indigenous practices, making it challenging to verify the information obtained. Moreover, there is a lack of evidence or well-documented data on the contribution of yams to food security and job opportunities in the study areas. Future studies should take these factors into consideration.

CONCLUSION

The study revealed that yam serves as a vital source of income, medicine, and food security for smallholder farmers, particularly when subsistence agriculture fails due to intermittent rainfall. Both biotic and abiotic environmental factors including stacking expenditures, land scarcity, poor soil fertility, lack of improved and drought-resistant landraces, animal attacks, absence of credit access, the unavailability of modern storage, market chain, capacity building training and agro-chemicals are among others factors that significantly limit yam distribution, production, and conservation of yam landraces. Addressing these challenges is critical to maintain and enhance yam diversity, ensuring crop sustainability and adaptability in the face of climate change. The study recorded a total of 27 yam landraces, with a range of 1 to 9 yam landraces per individual farm. The richness and diversity of yam landraces varied between the different districts and kebeles, with only a few landraces being abundant. The decline in diversity is likely due to farmers withdrawing certain landraces. The occurrence of yam landraces varied along altitudinal gradients, across farming units, and among different cultural groups, potentially influenced by preferences, farmers' curiosity, environmental factors, community traditions, and market demand. These factors collectively affect yam resource diversification. For instance, yams, once a staple food, are now becoming a supplementary crop, facing threats due to genetic erosion. This highlights the urgent need for landrace conservation to reverse the situation. There was also cultural influence on women's participation in yam production and their control over income, urging field officers to educate farmers on this issue. Urbanization, industrialization, and over-exploitation are rapidly threatening indigenous knowledge, therapeutic uses, and food potential of *Dioscorea* species. Thus, encouraging and promoting traditional yam-based agriculture systems is crucial for transferring indigenous knowledge to younger generations and preserving agro-biodiversity, which is currently maintained by only a few farmers due to various challenges. Harmonizing indigenous and scientific knowledge is imperative to maximize the potential of *Dioscorea* species for food security and health benefits, particularly in developing countries. Enhancing research and development of underutilized crops like yam plays a crucial role in adapting to climate change impacts and ensuring food security. The study recommends several strategies to improve yam production, productivity, and profitability in Ethiopia: (1) Ethiopia requires policies, research, technology adoption, creating awareness, increasing yam land cover (cultivation), and improving access to agrochemicals for disease management; (2) increasing research on advanced seed tuber production technologies, developing multiple stress-tolerant landraces, adopting innovative technologies, and promoting value-added processing; (3) providing access to credit, extension services, and establishing roust market chain; (4) optimizing fertilizer application rates; (5) providing capacity building training for farmers' on yam landrace conservation and utilization to preserve richness and diversity in both lower and higher distribution areas; (6) establishing seed-producing co-operatives for farmer-preferred yam varieties and improving storage structures; (7) providing breeding and quick propagation technologies to end users; (8) recognizing or awarding champion yam cultivators and ensuring ex situ conservation through the establishment of field gene banks and specialized gardens; (9) promoting yam as a functional food source at both local and national levels to ensure food security. Given these strategies, yam production has significantly improved the livelihoods of Nigerian farmers and holds similar promise for Ethiopian farmers.

ACKNOWLEDGMENTS

Local communities in the Basketo Special Zone, and the Daramalo and Offa districts, are highly acknowledged for their significant contributions to preserving the valuable yam crop and sharing their indigenous knowledge. The local administrations and assistants are also highly accredited for their facilitation and instrumental roles in the success of our field surveys in the study areas. The authors appreciate the reviewers and associate editor for their insightful comments and suggestions, which have significantly improved the quality of this paper.

DATA AVAILABILITY

The data used to support the findings of this study are available from the corresponding author upon reasonable request.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

CONTRIBUTION STATEMENT

B.K was the lead for conceptualization, methodology, field surveys, data collection, data curation, data analysis, writing original draft, writing review and editing. A.A., M.M., A.D, S.D., and W.A. conceived and designed the research procedures, supervised, validated, reviewed, and edited the manuscript, and proof read. All authors have read and agreed to the published version of the manuscript.

FUNDIG

This research was funded by Addis Ababa University (Research and Technology Transfer awarded a thematic research project grant and logistic support, RD/PY-018/2021) and Hawassa University (NORAD Project provided partial funding, grant number AVP/05/167/15).

ETHICS APROVAL AND CONSENT TO PARTICIPATE

Not applicable since our study focused only on plants. Informed consent for all participants was included in the questionnaire. Additionally, formal permission letters were secured for the respective district and Kebele administrative offices (Ref. No: Bio/79/2016 E.C/2024 G.C).

REFERENCES

Agidew AMA, Singh KN (2018) **Determinants of food insecurity in the rural farm households in South Wollo Zone of Ethiopia: the case of the Teleyayen sub-watershed**. *Agricultural and Food Economics* 6:1–23.

Baressa A, Itefa D (2019) **Ethnobotany and Nutritional Value of Two Domestic Yams (*Dioscorea* spp.) in Abaya Woreda, Southern Ethiopia.** *Ethnobotany Research and Applications* 18:1–10.

Belachew G, Bewuketu H, Aklilu A (2017) **Distribution, Diversity and Potential Production of Yams (*Dioscorea* spp.) in Sheko District, Southwest Ethiopia.** *American Journal of Life Sciences* 5:86–92.

Bhandari MR, Kasai T, Kawabata J (2003) **Nutritional Evaluation of Wild Yam (*Dioscorea* spp.) Tubers of Nepal.** *Food Chemistry* 82:619–623.

Bikila A, Abraham N, Girma C, Tilahun W, Negash T, Lelise A, Daniel M, Meseret N (2015) **Registration of 'Bulcha' and 'Lalo' Yam Varieties**. *East African Journal of Sciences* 9:65–68.

Byerlee DR, De Janvry AF, Klytchnikova II, Sadoulet EML, Townsend R (2008) **World Development Report 2008: Agriculture for Development; World Development Report No. 30; World Bank Group:** Washington, DC, USA, 2008..

Chandrasekara A, Kumar TJ (2016)**. Roots and tuber crops as functional foods: A review on phytochemical constituents and their potential health benefits**. *International Journal of Food Science* 1:3631647. .

CSA (2007) **Central Statically Agency Reports on Summary and Statistical Report of the 2007 Population and Housing Census**; CSA: Addis Ababa, Ethiopia, 2007.

CSA (2021) **Central Statically Agency Reports on Area and Production of Crops (Private Peasant Holdings, Meher Season)**; CSA: Addis Ababa, Ethiopia, 2021.

CSA (2020) **Central Statically Agency Reports on Crop Production Forecast Sample Survey on Area and Crop Production Forecast for Major Crops, Meher Season**; CSA: Addis Ababa, Ethiopia, 2020.

Condé N, George B, Maimouna T, Benedetta G, Martin C, Sékou M, P, Charlotte C, Philippa R (2025). "**The biocultural heritage and changing role of indigenous yams in the Republic of Guinea, West Africa**." *Plants, People, Planet* 7(3):719-733.

Demilew D (2022) **Food and Nutritional Security Impact of Exploiting Opportunities and Developing Strategies in Increase Yam (*Dioscorea* Spp.) Production in Ethiopia.** *J. Genetic Engineering and Biotechnology Research* 4: 230–238.

Ekanayake IJ, Asiedu R (2003) **Problems and Perspectives of Yam-based Cropping Systems in Africa**. *Journal of Crop Production* 9:531–558.

FAO (2009) **Agricultural Growth in West Africa, Market and Policy Drivers; Frank Hollinger (Food and Agriculture Organization of the United Nations), Michigan State University:** East Lansing, MI, USA, 2009.

FAO, IFAD, UNICEF, WFP, WHO (2021) **The State of Food Security and Nutrition in the World 2021. Transforming Food Systems for Food Security, Improved Nutrition and Affordable Healthy Diets for All**; FAO: Rome, Italy, 2021. doi: 10.4060/cb4474en.

FAOSTAT (2020) **Food and Agriculture Organization Corporate Statistical Database (FAOSTAT); FAO: Rome, Italy, 2020.** [`http://www.fao.org/faostat/en/#data/QC`] accessed on 5 December 2022.

Feleke ST, Kilmer RL, Gladwin CH (2005). **Determinants of food security in Southern Ethiopia, at the household level**. *Agricultural Economics* 33:351–363.

FAO (2018) **Food and Agricultural Organization. Cassava Production Guidelines for Food Security and Adaptation to Climate Change in Asia and Africa (No. IAEA-TECDOC-1840); Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture; FAO:** Rome, Italy.

Frossard E, Aighewi BA, Aké S, Barjolle D, Baumann P, Bernet T, Dao D, Diby LN, Floquet A, Hgaza VK (2017) **The Challenge of Improving Soil Fertility in Yam Cropping Systems of West Africa**. *Frontiers in Plant Science* 8(1953): 1-8.

Hildebrand E, Demissew S, Wilkin P (2002) **Local and regional landrace disappearance in species of Dioscorea L. (Yams) in Southwest Ethiopia**. In Ethnobiology and Biocultural Diversity, Proceedings of the 7th International Congress of Ethnobiology, Athens, Georgia, USA (23–17 October 2000, in); Stepp, J.R., Wyndham, F.S., Zarger, R.R., Eds; University of Georgia Press: Athens, GA, USA, pp 678–695.

Kothari CR (2004). **Sample Size Determination. Research Methodology**. *New Age International Publication* 1: 74–81. `https://www.fao.org/4/y9421e/y9421e05.htm`, accessed on 6 December 2024

Lebot V (2009) **Tropical Root and Tuber Crops Cassava, Sweet Potato, Yams and Aroids Crop Production Science in Horticulture**; CABI: Wallingford, CT, USA, Volume 17.

Lebot V, Faloye B, Okon E, Gueye B (2019) **Simultaneous Quantification of Allantoin and Steroidal Saponins in Yam (Dioscorea spp.) Powders**. *Journal of Applied Research on Medicinal and Aromatic Plants*13:8.

Magurran AE (1988) **Ecological Diversity and Its Measurement**; Princeton University Press: Princeton, NJ, USA, pp7–101.

Massawe FJ, Mayes S, Cheng A, Chai HH, Cleasby PM, Symonds RC, Ho WK, Siise A, Wong QN, Kendabie P., Yanusaa Y, Jamalluddina N, Singha A, Azmanb R, Azam-Ali SN (2015) **The Potential for Underutilised Crops to Improve Food Security in the Face of Climate Change**. *Procedia Environtal Sciences* 29:140–141.

Matsumoto R, Ishikawa H, Asfaw A, Asiedu R (2021) **Low Soil Nutrient Tolerance and Mineral Fertilizer Response in White Guinea Yam (*Dioscorea rotundata*) Genotypes.** *Frontiers in Plant Science* 12:629762.

Miege J, Sebsebe D (1997) **Dioscoreaceae**. In Flora of Ethiopia and Eritrea; Edwards, S., Sebsebe, D., Hedberg, I., Eds.; A Joint Publication of the National Herbarium, Biology Department, AAU, Ethiopia and the Department of Systematic Botany, Uppsala University: Uppsala, Sweden, pp55–62.

Mignouna HD, Abang MM, Asiedu R (2008) **Genomics of yams, a common source of food and medicine in the tropics.** Genom. *Tropical Crop Plants* 1:549–570.

Mulualem T, Mekbib F, Hussein S, Gebre E (2022) **Yam Production Constraints, Farming Sys-**

tems and Farmer Preferred Traits in Ethiopia: Implication for Breeding and Conservation. Ethiopia. Journal of Crop Science 9:185–202.

Muluneh T, Becker HC, Mass BL (2008) **Diversity, Distribution and Management of Dam landraces (*Dioscorea* spp.) in Southern Ethiopia.** *Genetic Resources and Crop Evolution* 55:115–131.

Muluneh T, Heiko C, Becker B, Maass L (2011) **Comparative analysis of morphological and farmers' cognitive diversity in yam landraces (Dioscorea spp.) from Southern Ethiopia**. *Tropical Agriculture and Development* 55:28–43.

Muluneh T, Heiko C. Becker B, Maass L. (2007) **Genetic diversity in yam germplasm from Ethiopia and their relatedness to the main cultivated Dioscorea species assessed by AFLP markers**." *Crop Science* 47(4):1744-1753.

Norman M, Peasron C, Searle P (1995) **Yams (*Discorea* species).** In: *The Ecology of Tropical Food Crops*; Cambridge University Press: Cambridge, UK, pp 305–318.

Nweke FI (2016) **Yam in West Africa. Food, Money and More**; Michigan State University Press: East Lansing, MI, USA, p187.

Obidiegwu JE, Lyons JB, Chilaka CA. (2020) **The Dioscorea Genus (Yam)—An appraisal of nutritional and therapeutic potentials**. *Foods* 9(9):1304.

Oyetunji OJ, Kabeya M, Shiwachi H (2007) **Production of Mini-tubers From Vine Cuttings of White Yam (*Dioscorea rotundata*)**. *Journal of Applied Horticulture* 9:167–172.

Pascual U, Narloch U, Nordhage S, Drucker A.G (2011) **The Economics of Agro-biodiversity Conservation for Food Security under Climate Change**. *Econ. Agrar. Recur. Nat.* 11: 191–220.

Petros S, Abay F, Desta GO, Brien C (2018) **Women farmers' empowerment compared to men farmers in Ethiopia**. *World Medicine and Health Policy* 10:220–245.

Sahore GJ, Kamenan NA (2007) **Changes in Nutritional Properties of Yam (*Dioscorea spp.*), Green Plantain (*Musa* spp.) and Cassava (*Manihot esculenta*) During Storage.** *Food Science and Technology* 47:81–88.

Scott GJ (2020) **A review of root, tuber and banana crops in developing countries: past, present and future**. *International Journal of Food Science and Technology* 56:1093–1114.

Sebsebe D, Nordal I, Stabbetorp POE (2003) **Flowers of Ethiopia and Eritrea: Aloes and other Lilies**, 1st ed.; Shama Books: Addis Ababa, Ethiopia.

Simpson EH (1949) **Measurement of diversity**. *Nature* 63: 688. doi: 10.1038/163688a0.

Subba HK, Dahal Y, Mafchan BR, Ghalley SK, Koirala BS (2023) **The Environment factors influencing abundance and growth of wild yam in broadleaved forest, Tsirang District, Bhutan**. *European Journal of Ecology* 9: 23–30.

Tchabi A (2010) **Efficacy of indigenous arbuscular mycorrhizal fungi for promoting white yam (*Dioscorea rotundata*) growth in West Africa.** *Appl. Soil Ecol.* 45: 92–100.

Temesgen T, Rashid MH (2009) **Economic Impact of Climate Change on Crop Production in Ethiopia: Evidence from Cross-section Measures**. *Journal of Center for Study of African Economy (CSAE)* 18:529–554.

Tizazu G (2019) **Yam landrace diversity and distribution in Basketo and Dera Malo Districts, Southwest Ethiopia**. *OMO International Journal of Science* 2:45–58. .

Tsegaye B (2021) **Diversity of Cultivated and Wild Yams (*Dioscorea* spp.) in Southwest Ethiopia Based on Farmers Management Practices, Agro-Morphological Traits and Nutritional Composition.** Ph.D dissertation, Hawassa University, Hawassa, Ethiopia.

USDA (2015) **Dietary Guidelines Advisory Committee. Scientific report of the Guidelines Advisory Committee (Washington (DC): USDA and US Department of Health and HumanServices**). [https://www.dietaryguidelines.gov/sites/default/files/2019-05/20152020_Dietary_Guidelines.pdf] Accessed, 8 June 2025.

Viruel J, Cataltaeya M, ShiwMoragues JG (2010) **New microsatellite loci in the dwarf yams Dioscorea group Epipetrum (Dioscoreaceae).** *American Journal of Botany* 97: e121–e123.

Wendawek A, Firew K, Feleke W, Sebsebe D, Wilkin P (2021) **An Illustrative Guides to the Farmers' Varieties of Yam (Dioscoria spp.) in Basketo Special District and Adjoining Woredas in Gamo and Wolayta Zones, Southern Ethiopia**; Addis Ababa University press: Addis Ababa, Ethiopia, 2021.

Yeshitila M, Temesgen D (2016). **Exploration and Collection of Root and Tuber Crops in East Wollega and Ilu Ababora zones: Rescuing Declined Genetic Resources.** *Indian Journal of Traditional Knowledge* 15: 86–92.

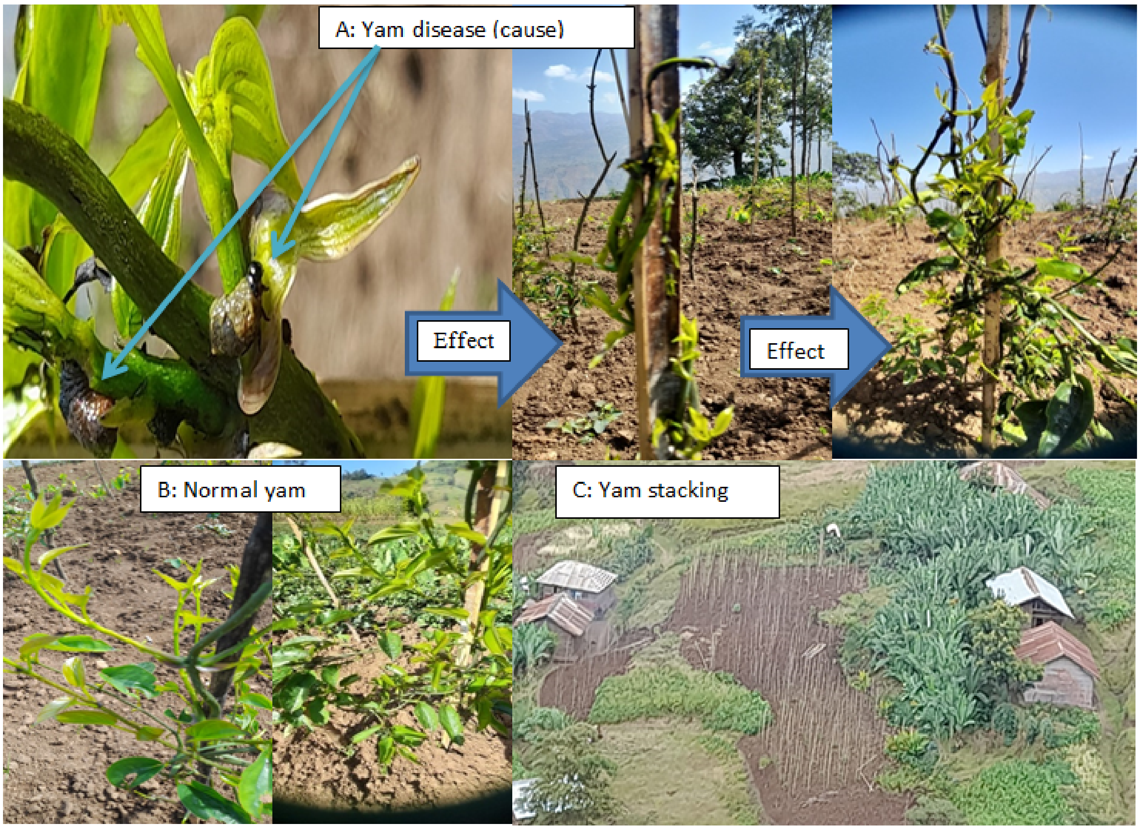
Zinash D (2008) **Minimizing Postharvest Losses in Yam (*Dioscorea* spp.): Treatments and Techniques.** In: Using Food Science and Technology to Improve Nutrition and Promote National Development; Robertson, G.L., Lupien, J.R., Eds.; International Union of Food Science and Technology: Guelph, ON, Canada, 2008.

Received: 20 March 2025
Accepted: 07 July 2025
Published: 10 June 2025

Editor: Natalia Hanazaki

Additional Files

Add File 1. Yesha; with broad leaves, sour taste and used as medicinal plant, Shella kanibolla Kebele, Basketo Special Zone (A). Ochie/Ocha; Kaleb Kassaye farm, Menena Selo Kebele, Daramalo district (B).



Add File 2. Yam disease (A), Normal yam (B) and yam stacking (C) at Menena Selo Kebele of Daramalo district.

Add File 3. Taro (left) and Cassava (right) farm at the study area (Photo by Birhanu K., 15/12/2023).