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Indigenous Knowledge, Traditional Cropping Systems, and Soil Fertility Management Practices Among Sorghum Farmers in Hararghe Zone, Oromia, Ethiopia

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Abstract

This study documents indigenous knowledge, traditional cropping systems, and soil fertility management practices among sorghum farmers in the Hararghe Zone of Oromia, Ethiopia, and identifies constraints affecting their continued use. A cross-sectional mixed-methods approach was employed involving 104 randomly selected households from Chiro, Mieso, and GulBordodde districts, complemented by informal interviews and group discussions. Data were analyzed using descriptive statistics and thematic analysis. Results showed that sorghum production remains strongly supported by indigenous knowledge and farmer-managed practices. Although 57.7% of farmers cultivated improved varieties, 81.8% relied on saved seed, demonstrating the importance of informal seed systems. Crop rotation (47.1%) and intercropping (37.5%) were the dominant cropping systems, with maize, common bean, and chickpea as major companion crops. Soil fertility management relied mainly on crop rotation (50.0%) and animal manure application (37.5%), with farmers combining multiple practices across cropping periods. Farmers showed high awareness of soil fertility improvement and conservation practices; however, limited access to inputs, pest and disease pressure, weak extension services, land scarcity, and labor constraints hindered wider application. The study highlights the need to integrate indigenous knowledge with scientific innovations and institutional support to improve soil fertility, productivity, and resilience of smallholder sorghum systems.

Introduction

Sorghum (*Sorghum bicolor* (L.) Moench) is a major cereal crop in sub-Saharan Africa, supporting the food security and livelihoods of nearly 300 million people, particularly in semi-arid and drought-prone regions where other cereals perform poorly (Food and Agriculture Organization [FAO], 2019). In Ethiopia, sorghum ranks among the most important staple crops in terms of production volume, cultivated area, and agro-ecological suitability, especially in low-input and moisture-stressed environments (Central Statistical Agency [CSA], 2016). Despite these advantages, sorghum production systems remain characterized by low productivity and high vulnerability to climatic and edaphic stresses.

A central constraint to sorghum productivity is the progressive decline in soil fertility, compounded by erratic rainfall, temperature extremes, pests, diseases, and weed pressure (Strange & Scott, 2005; Gregory et al., 2005). In semi-arid landscapes, substantial portions of seasonal rainfall are lost through evaporation, further limiting water availability to crops (Kinama et al., 2005). At the same time, population pressure and land scarcity have curtailed traditional long-fallow systems that historically replenished soil nutrients, forcing smallholders into continuous cultivation with limited access to external inputs. These dynamics have intensified soil degradation and undermined the sustainability of sorghum-based farming systems.

Paradoxically, sorghum is increasingly devalued socially and economically, often perceived as a “poor man’s crop.” This stigma has contributed to a shift toward maize cultivation, even in agro-ecological zones poorly suited to maize production (Dicko et al., 2006; Orr et al., 2016). Beyond agronomic consequences, this shift has accelerated the erosion of indigenous sorghum varieties and weakened the transmission of local knowledge related to cropping systems, soil fertility management, and adaptation to marginal environments.

Ethiopian smallholder farmers possess extensive indigenous knowledge developed through long-term interaction with local ecosystems. This knowledge encompasses soil and water conservation practices, crop rotations, intercropping arrangements, and biodiversity management strategies that enhance productivity and resilience under low-input conditions (Talawar & Rhodes, 1998). Intercropping and crop rotation, in particular, are widely recognized for their roles in improving nutrient cycling, stabilizing yields, reducing risk, and maintaining soil health. Globally, crop mixtures continue to contribute a substantial share of food production, especially in smallholder systems (Altieri, 1991; Altieri, 1999; Brooker et al., 2015).

Despite growing recognition of indigenous knowledge as a critical component of sustainable agriculture, empirical evidence documenting how traditional sorghum-based cropping systems are currently practiced, maintained, or constrained remains limited in eastern Ethiopia. Existing research and extension efforts have largely emphasized externally derived technologies, often overlooking farmers’ experiential knowledge and the socio-ecological factors shaping its application (Rickards et al., 2025). As a result, locally adapted practices that could contribute to soil fertility restoration, climate resilience, and sustainable intensification remain poorly integrated into agricultural development strategies.

This study addresses this gap by documenting the traditional cropping systems, production and postharvest practices used by sorghum farmers in the Hararghe Zone of Oromia Regional State. It further assesses farmers’ awareness and perceptions regarding indigenous knowledge and the effectiveness of their traditional soil fertility management practices, while identifying the key constraints affecting the continued use, preservation, and intergenerational transmission of these practices. By empirically grounding indigenous knowledge within contemporary sorghum production systems, the study contributes evidence relevant to sustainable land management, climate-resilient agriculture, and the development of context-specific agricultural policies and extension.

Methodology

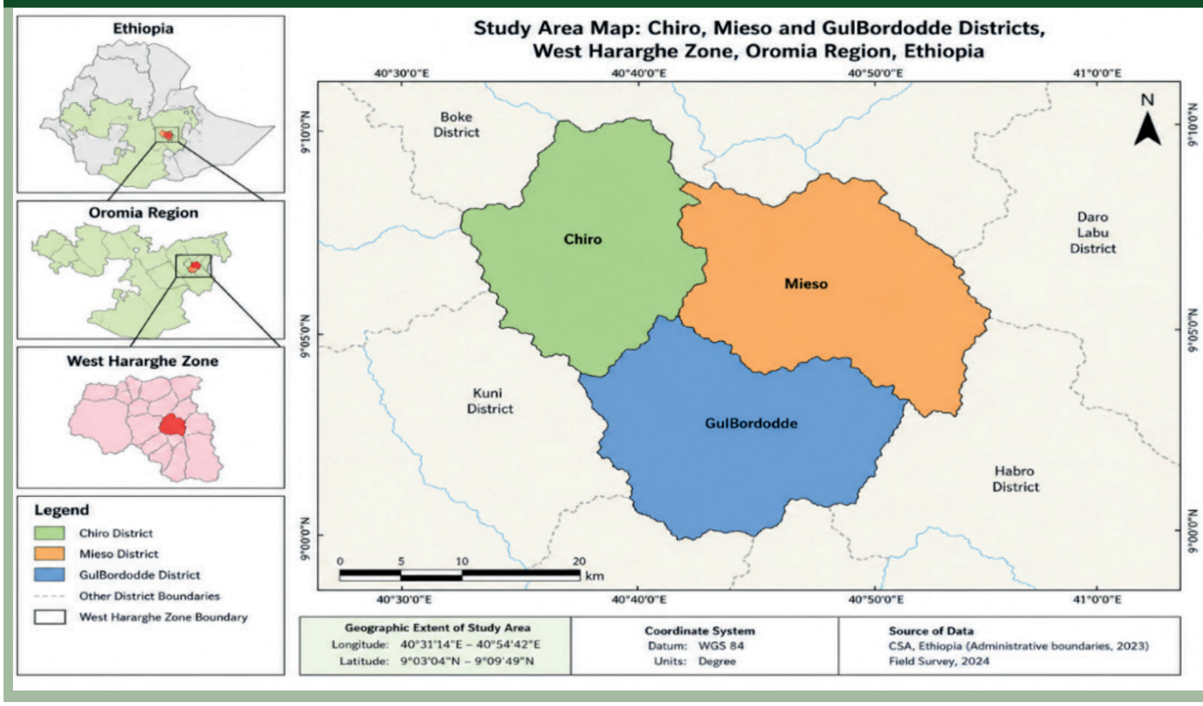
Study Area

This research was carried out in three selected sorghum-growing districts—Chiro, Mieso, and GulBordodde—situated in the West Hararghe Zone of the Oromia Regional State, Ethiopia. Geographically, the study area lies within approximately 40°31'14" E to 40°54'42" E longitude and 9°03'04" N to 9°09'49" N latitude (Figure 1).

These districts were purposefully chosen because of their strong reliance on sorghum production and their representativeness of smallholder, rainfed, and low-input agricultural systems in eastern Ethiopia. In this region, sorghum serves as a major staple crop that contributes significantly to household food security, income generation, and adaptation to local agroecological conditions.

Figure 1

Study Area Map



Study Design

A cross-sectional mixed-methods design was applied, combining quantitative household survey data with qualitative insights obtained through informal conversational interviews and small group discussions. The integration of both approaches allowed cross-validation of findings and a more holistic understanding of indigenous knowledge systems related to crop production and soil fertility management.

Rather than developing a separate semi-structured interview or focus group discussion guide, the study utilized selected key questions extracted from the structured questionnaire. These questions were used flexibly as discussion prompts to encourage open-ended interaction with participants.

Sampling Procedure and Sample Size

A multistage sampling approach was employed. Initially, Chiro, Mieso, and GulBordodde districts were purposively selected based on their prominence in sorghum cultivation and relevance to traditional farming knowledge systems. In the second stage, kebeles (the smallest administration units) and eligible farming households were identified using official lists obtained from local agricultural extension offices. From these lists, households were randomly selected by assigning identification numbers and applying a random selection procedure to ensure equal chance of inclusion.

A total of 104 households participated in the study. The sample size was determined based on logistical feasibility and the need to capture variation across the three districts. The final distribution of respondents was proportional: Chiro (n=35), Mieso (n=35), and GulBordodde (n=34)

To complement the household survey, a qualitative component was conducted using purposive sampling. Ten key informants, comprising experienced sorghum farmers and community elders recognized for their extensive knowledge of indigenous farming practices, were selected across the three districts. Key informant interviews continued until data saturation was achieved, whereby additional interviews no longer yielded new themes or insights.

Data Collection

Data were gathered simultaneously using both quantitative and qualitative techniques. For the quantitative data collection, a structured questionnaire covering socio-demographic characteristics, landholding size, sorghum production practices, soil fertility management methods, cropping patterns, input use, and household livelihood assets. Before the main survey, the questionnaire was pre-tested in a similar but non-sampled area, and necessary adjustments were made to improve clarity and cultural relevance.

Qualitative information was obtained through informal conversational interviews and small group discussions with selected farmers and key informants. No separate semi-structured or focus group discussion guide was prepared. Instead, selected questions derived from the structured questionnaire were used as flexible prompts to guide discussions and encourage participants to freely express their knowledge and experiences. The discussions explored indigenous soil fertility management practices, traditional cropping systems, mechanisms of knowledge transfer, and constraints limiting the use of indigenous practices. All sessions were documented through detailed note-taking, with summaries prepared immediately after each discussion.

Regarding ethical considerations, prior to data collection, informed consent was obtained from all participants after clearly explaining the objectives of the study, the terms of voluntary participation, and the right to withdraw at any time. Indigenous knowledge shared by participants was treated with respect for local cultural values and intellectual property considerations. All data were used exclusively for academic research purposes.

Data Analysis

Quantitative data were coded and analyzed using SPSS version 25. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarize household characteristics, production practices, indigenous knowledge indicators, and soil fertility management strategies. For questions involving multiple responses, frequencies and percentages were calculated based on the total number of respondents (N=104), and percentages were interpreted as non-mutually exclusive where applicable.

Qualitative data obtained from interviews and group discussions were organized, coded, and analyzed thematically. Emerging themes were used to explain and contextualize quantitative findings. Data triangulation was applied by comparing information obtained from household surveys, informal interviews, and group discussions to improve the reliability and validity of the findings.

Results and Discussion

Survey Participant Demographics

Respondents' age was grouped into four analytical categories (20–30, 31–40, 41–50, and >50 years) to examine variations in farming characteristics across different life stages. These categories broadly represent young, early middle-aged, late middle-aged, and older farmers, reflecting potential differences in labor availability, farming experience, technology adoption, and decision-making. The age groups were developed for analytical purposes and do not represent universally accepted classifications.

The socio-demographic characteristics of respondents indicate a predominantly male (94.2%) and middle-aged farming population, with the majority (52.9%) aged 31–40 years (Table 1). This represents a largely labor-active farming group engaged in sorghum production. The low proportion of female respondents (5.8%) may reflect differences in household roles, or gender participation in sorghum farming and decision-making, and should therefore be interpreted with caution.

Marital status was overwhelmingly dominated by married households (97.1%), indicating stable household labor structures that support agricultural production. Educational attainment was generally low, with 45.2% having no formal education and only 1% attaining tertiary education. This low literacy level has important implications for extension delivery, as it may constrain the effectiveness of written training materials and suggests a need for more visual, oral, and demonstration-based extension approaches to support technology adoption.

Table 1

Socio-Demographics of Participants

Parameters	Frequency	Percentage (%)
Age groups (Years)		
20-30	18	17.3
31-40	55	52.9
41-50	23	22.1
Above 50	8	7.7
Sex		
Male	98	94.2
Female	6	5.8
Marital status		
Married	101	97.1
Unmarried	33	2.9
Education		
No formal education	47	45.2
Primary education	36	34.6
Secondary education	5	4.8
Tertiary education	1	1.0
Adult education	12	11.5
Koranic/Church	3	2.9
Main occupation		
Crop Farming	101	97.1
Formal work/ public service	3	2.9
Household head		
Yes	100	96.2
No	4	3.8
Sorghum farming experience (Years)		
1-10	50	48.1
11-20	38	36.5
> 20 years	16	15.4

Despite low formal education, respondents had varying levels of sorghum farming experience, with 48.1% reporting 1–10 years of experience, 36.5% reporting 11–20 years, and 15.4% reporting more than 20 years (Table 1). This diversity in farming experience suggests that practical knowledge accumulated through years of cultivation, alongside indigenous knowledge, plays an important role in guiding sorghum production decisions.

Household Asset Ownership and Implications

The study revealed that household ownership of media and transport assets (Figure 2) varied widely. Radios were owned by 41 households (39.4%), providing a common source of information for farmers, while 63 households (60.6%) did not own a radio. Cell phones were present in 35 households (33.6%), offering potential access to mobile agricultural advice, but 69 households (66.4%) lacked this device. Television ownership was low, with only 13 households (12.5%) having a TV, limiting exposure to visual educational programs. Motorized transport, specifically Motor King vehicles, was rare, owned by just 7 households (6.7%), and tractors were almost nonexistent, with only 1 household (1.0%) possessing one.

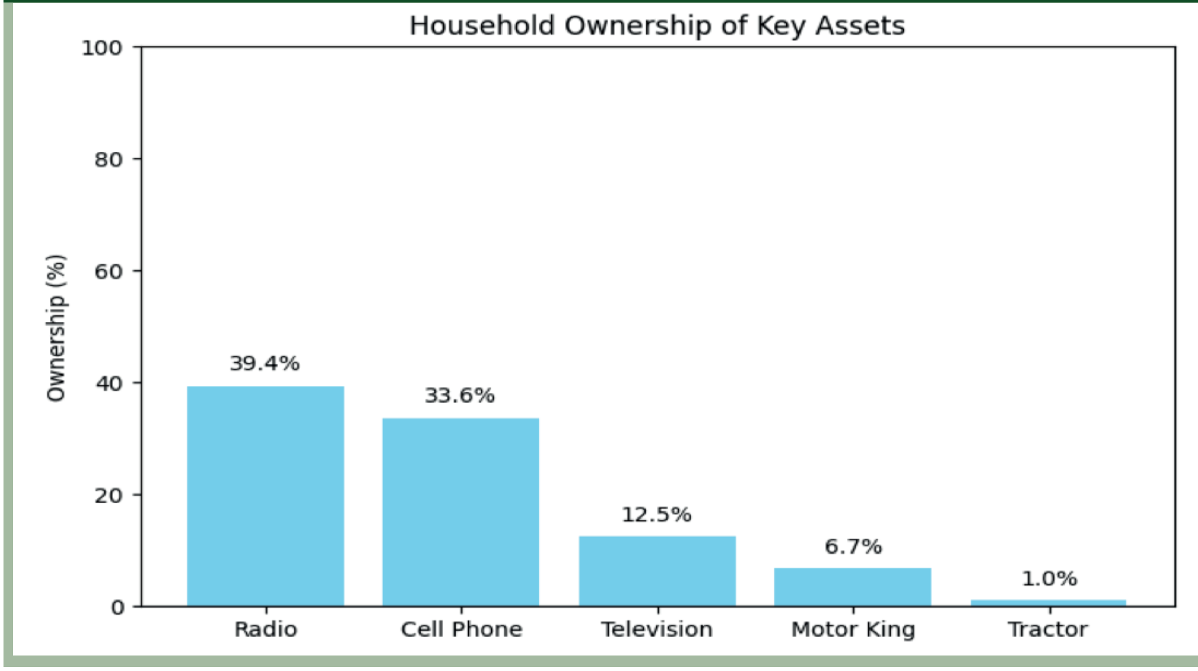
The implications of these findings are significant. Access to information is a critical factor for agricultural productivity. Ownership of radios and cell phones allows farmers to receive timely weather updates, market prices, and farming advice, which supports better decision-making in crop management and harvesting. However, the low ownership of televisions suggests that visual demonstrations and modern agricultural programming reach only a small fraction of households, potentially limiting knowledge transfer.

Mobility and mechanization are equally important for farming efficiency. Motorized transport, even if limited, improves farmers' mobility, allowing them to access markets, transport inputs, and connect with agricultural support networks. The near absence of tractors indicates minimal mechanization, constraining land preparation and large-scale farming activities. Consequently, most households continue to rely on labor-intensive traditional cropping methods, which may limit productivity and income generation.

Finally, the findings highlight implications for livelihood resilience. In the Horn of Africa, where agriculture is the primary livelihood for the majority of the population (FAO, 2020), even modest access to communication and transport assets enhances farmers' ability to sustain traditional cropping systems and adapt to environmental and market challenges. Conversely, limited asset ownership may hinder the adoption of improved agricultural practices, reduce efficiency, and restrict opportunities for economic growth.

Figure 2

Percentage of Households Owning Key Assets



Farm Characteristics and Production Purpose

Farm size was generally small, with an average total landholding of 1.25 ha per household, of which 0.74 ha was allocated to sorghum production (Table 2). Farms were located at an average distance of 1.18 km from homesteads, reflecting decentralized production fields typical of smallholder systems.

Land tenure was dominated by inheritance (70.2%) and government allocation (24%), while land purchase and rental were minimal (5.8%). This confirms a structurally constrained land market, consistent with Ethiopia's customary and state-managed tenure system, which limits land consolidation and mechanization potential (Benin et al., 2006).

Production purpose was mixed: 57.7% of farmers produced sorghum for both consumption and market, while 42.3% produced solely for subsistence. This agrees with CSA (2016), which reports sorghum as a primarily subsistence crop in Ethiopia.

Table 2

Sorghum Farm Characteristics

Parameters	Frequency	Percentage (%)
Land ownership		
Inherited	73	70.2
Government allocated	25	24.0
Purchased/rented	6	5.8
Production purpose		
Consumption only	44	42.3
Consumption + market	60	57.7
Sorghum land (ha)	0.74	-
Total land (ha)	1.25	-
Distance (km)	1.18	-

Seed Systems and Genetic Diversity

Although 57.7% of respondents cultivated improved sorghum varieties, the majority (81.8%) obtained seed from their own saved seed, while only 9.6% acquired seed through gift or exchange, 6.7% through purchase from local market/other farmers, and 1.9% directly from agro-dealers

(Table 3). This indicates that improved varieties are largely maintained and disseminated through informal seed systems, particularly farmer-saved seed, rather than through commercial seed suppliers. Farmers commonly recycle seed from previous harvests and may also exchange improved seed within their communities, reducing reliance on agro-dealers and formal seed markets (Ethiopian Institute of Agricultural Research [EIAR], 2021; CSA, 2023; Ministry of Agriculture [MoA], 2022).

Fourteen sorghum landraces, dominated by Mako, Shefare, and Abdalota, were identified, indicating high genetic diversity, which is critical for adaptation to drought and climate variability. Similar dominance of landraces has been reported in West Africa (Vom Brocke et al., 2014; Smale et al., 2018; Ahmad et al., 2022). Seeding rates varied widely, from 1–10 kg ha^{-1} (75%) to 21-30 kg ha^{-1} (4.8%), with higher rates often applied to landraces under rainfed conditions to compensate for poor germination, uneven moisture, and broadcast sowing (EIAR, 2021).

The persistence of local landraces demonstrates farmers' continued preference for traits such as drought tolerance, storability, and cultural suitability, despite the use of improved varieties. This is consistent with findings from other African sorghum production systems, where landraces and improved varieties coexist. Although 57.7% of respondents cultivated improved varieties, most farmers (81.8%) relied on farm-saved seed, indicating that seed is predominantly sourced through informal seed systems. The wide variation in seed rates further suggests differences in farmers' planting practices, highlighting variability in the application of recommended agronomic practices.

Table 3

Sorghum Seed System

Parameters	Frequency	Percentage (%)
Seed type		
Improved	60	57.7
Landrace	44	42.3
Seed source		
Saved seed	85	81.8
Gift/exchange	10	9.6
Purchased from local markets/Other farmers	7	6.7
Purchased from Agro-dealers	2	1.9
Seed usage (Kg ha^{-1}.)		
1-10	78	75.0
11-20	21	20.2
21-30	5	4.8

Soil Fertility Status and Fertilizer Use

Farmers perceived their soils as moderately fertile (48.1%), fertile (30.8%), and infertile (21.2%) (Table 4). However, this perception-based classification was not supported by soil testing, as only 16.3% of respondents conducted laboratory soil analysis. This discrepancy indicates that soil fertility management is largely guided by experiential perception rather than scientific assessment, which may lead to suboptimal fertilizer application decisions.

Organic amendments dominated soil management strategies (65.4%) were widely used, while 34.6% used chemical fertilizers (NPS and urea). The dominance of organic inputs reflects limited access to chemical fertilizers and strong reliance on livestock-based farming systems.

The heavy reliance on organic fertilizers indicates a low-input agricultural system where soil fertility is maintained through recycling rather than external nutrient inputs. However, the limited use of soil testing suggests inefficiencies in nutrient management and potential nutrient depletion over time.

Tillage and Weed Management Practices

Minimal tillage was the most commonly practiced tillage system, reported by 56.7% of respondents, followed by tractor ploughing (41.3%), while only 1.9% practiced zero tillage (Table 5). Weed management was primarily conducted manually (59.6%), whereas 38.5% of respondents practiced biological weed control and only 1.9% relied on chemical herbicides.

The predominance of minimal tillage suggests that many farmers adopt soil management practices that minimize soil disturbance while supporting

Table 4

Soil Fertility Status & Fertilizer Use

Parameters	Frequency	Percentage (%)
Soil fertility perception		
Fertile	32	30.8
Moderate	50	48.1
Infertile	22	21.2
Soil type		
Loam	71	68.3
Clay	15	14.4
Sandy	13	12.5
Others	5	4.8
Fertilizer		
Organic	68	65.4
Chemical (NPS, Urea)	36	34.6
Performed soil fertility test		
No	17	16.3
Yes	87	83.7

Table 5

Tillage and Weed Management

Parameters	Frequency (n=104)	Percentage (%)
Tillage system		
Minimum tillage	59	56.7
Tractor ploughing	43	41.3
Zero tillage	2	1.9
Weed management		
Manual	62	59.6
Biological	40	38.5
Chemical	2	1.9

crop production. Reduced soil disturbance can contribute to maintaining soil structure, reducing erosion, conserving soil moisture, and retaining organic matter, all of which support soil fertility, particularly under the moisture-limited conditions of the study area. The continued use of tractor ploughing by a substantial proportion of farmers, however, indicates that conventional land preparation remains an important component of local farming systems.

Manual weed control remains the principal weed management strategy, reflecting the limited use of herbicides among the surveyed households. The widespread reliance on manual and biological weed control indicates that weed management is largely achieved through labor-based and non-chemical approaches. These practices may reduce dependence on synthetic herbicides while complementing other soil fertility management practices, such as the application of organic amendments and crop residue management.

These findings are consistent with previous studies showing that conventional tillage suppresses weeds by burying weed seeds below favorable germination depths (Nakamoto et al., 2006). Likewise, manual and mechanical weed control remain the predominant weed management strategies among smallholder farming systems in sub-Saharan Africa because of limited access to herbicides and agricultural mechanization (Gianessi et al., 2009). Overall, the observed tillage and weed management practices demonstrate the continued reliance of smallholder farmers on labor-intensive and locally adapted approaches that contribute to sustainable crop production and soil resource management.

Traditional Cropping Systems: Practices, Perceptions, and Challenges

The traditional cropping systems practiced in the study area and associated characteristics are indicated in Tables 6, 7, and 8, respectively. They provide a snapshot of the various cropping systems mainly practiced in the study communities and cropping systems used by the respondents during the 2023 production season.

Cropping System

Crop rotation was the predominant sorghum-based cropping system, accounting for 47.1% of respondents, followed by intercropping (37.5%) and monocropping (15.4%) (Figure 3). Among farmers practicing intercropping, maize (39.4%) was the most common companion crop grown with sorghum, followed by common bean (30.8%) and chickpea (29.8%) (Figure 4). These findings indicate that farmers preferentially integrate sorghum with complementary food legumes and cereals to optimize land use and enhance production. This pattern is consistent with the observations of Okot et al. (2022), who reported that sorghum is commonly interspersed with companion crops within the same field, while it is also grown as an intercrop in fields where maize or legumes are the primary crops.

Farmer-Perceived Benefits from Traditional Cropping Systems

Farmers associated cropping systems with improved soil fertility (41.3%), pest and disease reduction (40.4%), and erosion control (18.3%) (Table 6). Crop rotation was perceived as the most beneficial practice for yield improvement (64.4%) and soil health enhancement (56.7%). These findings align with research conducted in the Tigray and Amhara regions of Ethiopia, which also indicated that farmers are well aware of the positive impacts of crop rotation on soil productivity. Many farmers in these regions reported rotating crops seasonally to enhance soil fertility, increase productivity, and manage pests and diseases effectively (Teshome et al., 2018; Teshome et al., 2019).

Figure 3

Distribution of the Main Traditional Sorghum-Based Cropping Practices

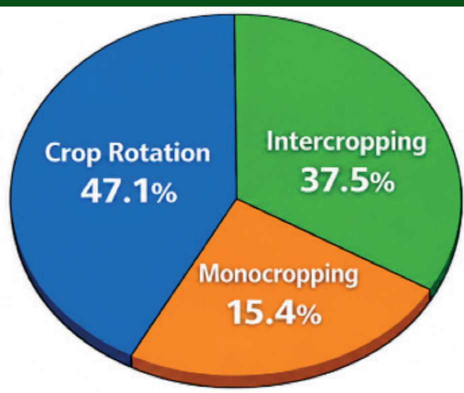
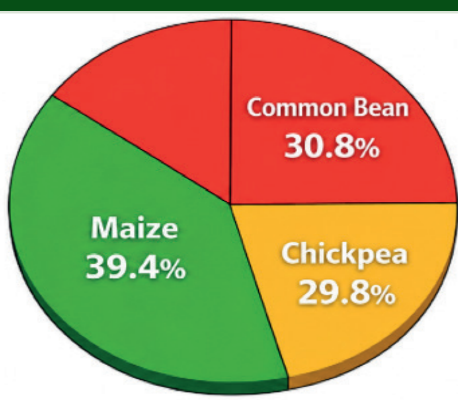


Figure 4

Component Crops Associated with Sorghum in Intercropping Systems



Challenges in Practicing Traditional Sorghum Cropping Systems

Farmers identified several constraints affecting the adoption of traditional sorghum cropping systems, including limited access to inputs (33.7%), pest and disease pressure (31.7%), and lack of technical knowledge (12.5%) (Table 7). Land scarcity and labour constraints were less frequently reported.

These challenges explain the persistence of low-input traditional systems despite farmers' awareness of improved practices. The dominance of input constraints suggests that structural barriers—such as inadequate access to agricultural inputs, extension services, and credit—play a more decisive role than knowledge gaps alone in limiting agricultural transformation. This finding reinforces the need for integrated support systems that address both resource and capacity limitations to enable farmers to translate their agronomic knowledge into practice.

Key informants emphasized that limited access to improved seed varieties, fertilizers, and extension services was the most pressing barrier. They noted that even when farmers understood the benefits of crop rotation or intercropping, they often lacked the resources to implement them effectively. Pest and disease outbreaks were

Table 6

Farmer-Perceived Benefits from Traditional Cropping Systems

Parameters	Frequency (n=104)	Percentage (%)
Improved fertility	43	41.3
Pest control	42	40.4
Reduced erosion	19	18.3
No response	0	0.0

Table 7

Challenges in Practicing Traditional Sorghum Cropping Systems

Parameters	Frequency (n=104)	Percentage (%)
Input access	35	33.7
Pest and diseases	33	31.7
Knowledge gap	13	12.5
Land access	7	6.7
Labor-intensive	1	1.0
Others	15	14.4
No response	0	0

also reported as increasingly difficult to manage due to climate variability and limited availability of affordable pesticides. Furthermore, some informants highlighted that traditional knowledge of indigenous soil fertility management (e.g., use of manure, crop residues, and composting) is declining, as younger farmers rely more on external inputs but struggle to access them. This reinforces the earlier point that structural barriers—rather than knowledge gaps alone—are the main constraints to transforming traditional sorghum systems.

Indigenous Soil Fertility Management

Table 8 summarizes the indigenous soil fertility management practices reported by the respondents (N=104). Farmers identified both their principal soil fertility management practice and the practices they commonly use in sorghum production. They were also asked to indicate all practices they typically combine to maintain soil fertility across multiple cropping periods; therefore, responses in the combined management category represent multiple responses and are not mutually exclusive.

Crop rotation, which involves alternating crops between successive growing seasons to improve soil fertility and disrupt pest and disease cycles, was the most frequently reported primary soil fertility management practice, being identified by 52 respondents (50.0%). Animal manure application, involving the use of livestock manure to improve soil organic matter and nutrient availability, ranked second, with 39 respondents (37.5%). Within sorghum production, crop rotation remained the dominant practice (42 respondents; 40.4%), followed by animal manure application (23 respondents; 22.1%).

When respondents were asked to identify all practices, they generally combine to improve soil fertility, animal manure was the most frequently reported component, being included by 91 respondents (87.5%), followed by crop rotation (71 respondents; 68.3%). This finding indicates that indigenous soil fertility management is predominantly based on integrated use of complementary practices rather than reliance on a single management option. Such integration is consistent with the principles of Integrated Soil Fertility Management, where organic nutrient inputs are combined with agronomic practices to improve soil productivity and sustainability (Vanlauwe et al., 2010).

Intercropping, defined as growing two or more crops simultaneously on the same field, was reported as a primary practice by 14 respondents (13.5%) and was included in combined management by 18 respondents (17.3%). Other practices were less frequently reported, including fallowing (7 respondents; 6.7%), composting (7 respondents; 6.7%), ash application (5 respondents; 4.8%), crop residue management (4 respondents; 3.8%), cover cropping (3 respondents; 2.9%), and mulching (2 respondents; 1.9%). Their relatively low adoption may reflect limited land availability, labour requirements, scarcity of biomass resources, and competing uses of crop residues, particularly as livestock feed in mixed crop–livestock production systems (Giller et al., 2009). Although crop residue management was reported more frequently within sorghum fields (16 respondents; 15.4%) than as a primary soil fertility management practice (3.8%), its limited inclusion in combined management (2.9%) suggests that crop residues are often diverted to other household uses, especially livestock feeding.

Overall, the results demonstrate that indigenous soil fertility management among sorghum-producing households relies primarily on crop rotation and animal manure application, while several other practices are employed as complementary measures depending on local resource availability and farming conditions.

Table 8

Indigenous Soil Fertility Management Practices Reported by Respondents (N=104)

Practice (brief description)	Primary practice n (%)	Practice used in sorghum production n (%)	Included in combined management* n (%)
Crop rotation (alternating crops between seasons)	52 (50.0)	42 (40.4)	71 (68.3)
Animal manure (application of livestock manure)	39 (37.5)	23 (22.1)	91 (87.5)
Intercropping (growing two or more crops simultaneously)	14 (13.5)	9 (8.7)	18 (17.3)
Fallowing (temporarily leaving land uncultivated)	7 (6.7)	3 (2.9)	11 (10.6)
Composting (application of decomposed organic materials)	7 (6.7)	1 (1.0)	5 (4.8)
Ash application (application of wood or crop ash to soil)	5 (4.8)	3 (2.9)	3 (2.9)
Crop residue management† (returning crop residues to the field)	4 (3.8)	16 (15.4)	3 (2.9)
Cover cropping (growing crops primarily to protect and enrich the soil)	3 (2.9)	4 (3.8)	2 (1.9)
Mulching (covering soil with plant materials to conserve moisture)	2 (1.9)	1 (1.0)	0 (0.0)

**Multiple responses were allowed for combined management; therefore, percentages are not mutually exclusive and do not sum to 100%.*
†Includes the retention and incorporation of crop residues into the soil.

Yield, Utilization, and Postharvest Management of Sorghum

Average sorghum yield was 2,237kg per 0.74ha of cultivated land (Table 9), i.e. 300kg per hectare, indicating moderate productivity under smallholder rainfed conditions.

A key finding of this study is the multi-purpose allocation of sorghum production, reflecting its central role in rural livelihood systems. As shown in Figure 5, sorghum output was distributed across five major use categories: household consumption, market sales, storage, seed reserve, gifts/social sharing, and postharvest losses.

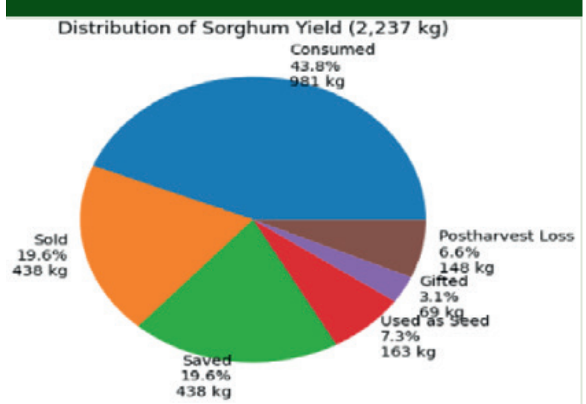
Table 9

Sorghum Yield

Variable	Mean
Total farm size (ha)	1.25
Sorghum land (ha)	0.74
Total sorghum yield (kg)	2,237.2

Figure 5

Distribution of Sorghum Yield



The dominance of household consumption confirms that sorghum remains primarily a food security crop, rather than a fully market-oriented commodity. This aligns with CSA (2016), which reported that the majority of sorghum in Ethiopia is retained for domestic use, with only a limited proportion entering markets.

The allocation of 438kg for market sales indicates that sorghum contributes to household cash income. However, these data alone do not necessarily demonstrate a shift toward commercial sorghum production. Rather, they suggest that farmers market part of their production after satisfying household consumption and other on-farm needs, with the quantity sold likely varying according to annual production levels, household food requirements, and market opportunities. Thus, sorghum remains primarily a food-security crop while also providing an important source of supplementary income through the sale of surplus grain.

The allocation of 438kg for storage underscores the importance of maintaining grain reserves to buffer seasonal food shortages, price fluctuations, and climate-related production risks. Similarly, the retention of 69kg for seed reflects the continued reliance on farmer-managed seed systems and supports the findings presented in Section 4.3, where informal seed sources were shown to predominate. Together, these allocation patterns highlight the multiple roles of sorghum in supporting household food security, income generation, and the continuity of local production systems.

Importantly, social functions of sorghum, represented by gifts (164kg), demonstrate its role in strengthening social networks and reciprocal labor/food exchange systems within rural communities.

Postharvest losses (147kg) represent a non-trivial proportion of production, indicating inefficiencies in harvesting, handling, and storage systems. This loss level is consistent with smallholder grain systems in sub-Saharan Africa, where traditional storage methods remain dominant (Tadesse, 2000; Haile, 2006).

Seed Storage Practices

Postharvest seed storage practices reflected the continued reliance on indigenous knowledge for maintaining seed quality (Table 10). Of the 104 respondents, 62 (59.6%) reported storing carefully selected healthy seed in containers, making it the most common storage method. Another 34 respondents (32.7%) stored seed by hanging it in the kitchen above the cooking area, while 8 respondents (7.7%) reported using both methods. These traditional storage practices are inexpensive, locally available, and well-adapted to local farming conditions. They enable farmers to preserve seed for subsequent cropping seasons and reinforce the continued reliance on farmer-managed seed systems. However, the effectiveness of these methods in maintaining seed quality may vary depending on storage duration, moisture conditions, and pest infestation.

Sorghum Residue Utilization

Sorghum residues were used for a variety of household and agricultural purposes, demonstrating the multifunctional role of sorghum within mixed farming systems (Table 11). Livestock feed was the predominant use, reported by 92 respondents (88.5%), emphasizing the strong integration of crop and livestock production in the study area. Other important uses included fuel or firewood (27 respondents; 26.0%) and fencing or weaving materials (19 respondents; 18.3%), while 5 respondents (4.8%) reported other uses. Because respondents could report more than one use, these data represent multiple responses and the percentages are therefore not mutually exclusive.

The predominance of livestock feed illustrates that sorghum residues are an essential component of household livestock production, particularly during periods of feed scarcity. Their additional use as fuel and construction materials further

Table 10

Seed Storage Practices Reported by Respondents (N=104)

Seed storage method	Frequency (n=104)	Percentage (%)
Selected healthy seed stored in containers	62	59.6
Hanging seed in the kitchen	34	32.7
Both methods	8	7.7
Total	**104**	**100.0**

demonstrates that sorghum contributes to household livelihoods beyond grain production. However, the extensive use of residues as livestock feed may reduce the quantity of crop residues available for incorporation into the soil, thereby limiting opportunities to improve soil organic matter and fertility. This trade-off is characteristic of mixed crop–livestock farming systems, where farmers must balance the competing demands for limited biomass resources.

Overall, these findings demonstrate that sorghum is a multifunctional crop that supports household food security, seed conservation, livestock production, household energy, and construction needs. Such diversified utilization enhances the resilience and sustainability of smallholder farming systems in the study area.

Local Knowledge Appraisal

The assessment of farmers' indigenous knowledge of soil amendments and cropping systems is presented in Tables 13 and 14. Overall, the findings indicate a strong foundation of experiential knowledge, particularly in relation to organic soil management and traditional cropping practices.

Indigenous Soil Fertility Management Awareness

The assessment of indigenous knowledge on soil fertility management awareness (Table 12) reveals a generally high level of awareness among farmers regarding the importance of organic soil management for sustaining soil quality and productivity. Nearly all respondents (98.1%)

Table 11

Uses of Sorghum Residues Reported by Respondents (N=104)

Sorghum residue use	Frequency (n=104)	Percentage (%)
Livestock feed	92	88.5
Fuel/firewood	27	26.0
Fencing/weaving	19	18.3
Other uses	5	4.8

Multiple responses were allowed; therefore, percentages are not mutually exclusive and do not sum to 100%.
No non-responses were recorded.

acknowledged that the use of compost, animal manure, minimum tillage, and cover crops enhances soil structure and increases soil organic matter. This widespread awareness reflects farmers' long-term experiential learning and reliance on locally available organic inputs.

Similarly, 96.2% of respondents recognized that cover crops—particularly legumes and grasses—play a crucial role in improving soil quality through increased organic matter, enhanced soil moisture retention, and reduced soil erosion. These findings are consistent with previous studies demonstrating that indigenous soil management practices often align with scientifically recommended sustainable land management strategies (Pretty, 2008; Lal, 2004).

However, despite this high level of awareness, earlier results (Table 8) show that only a small proportion of farmers actually practice cover cropping in sorghum-based systems. This discrepancy suggests the existence of a knowledge–practice gap, likely influenced by constraints such as land scarcity, labor demand, and limited access to planting materials. Although this study did not explicitly investigate these constraints, similar gaps have been widely reported in smallholder farming systems.

Awareness declines for practices that require modifications to conventional land preparation methods. Only 62.5% of respondents understood that reducing soil disturbance during planting helps preserve soil structure and minimizes erosion, while 63.5% recognized the benefits of applying farmyard manure, poultry manure, crop residues, and retaining crop stover in the field. These findings suggest that while farmers generally appreciate the value of organic inputs, conservation-oriented practices such as reduced tillage and residue retention are less consistently understood or adopted.

In many developing countries, agriculture is the primary source of livelihood, and land management decisions are closely linked to labor availability and immediate production needs (Barbier, 2003). As emphasized by Warren (1991), indigenous knowledge provides a critical foundation for sustainable agriculture, offering locally adapted solutions that can be strengthened through appropriate integration with scientific innovations.

Table 12

Indigenous Soil Fertility Management Awareness

Statement	Aware	Not aware	Total N (%)
The use of compost and animal manure, minimum tillage, and cover crops enhances soil structure and soil organic matter.	102 (98.1)	2 (1.9)	104 (100.0)
Cover crops, such as legumes and grasses, improve soil quality by increasing soil organic matter and soil moisture content and by reducing soil erosion.	100 (96.2)	4 (3.8)	104 (100.0)
Reducing the amount of soil disturbance during planting helps preserve soil structure and reduces soil erosion.	65 (62.5)	39 (37.5)	104 (100.0)
Application of farmyard manure, cow dung, poultry manure, and crop residues, including leaving stover on the field, improves soil quality.	66 (63.5)	38 (36.5)	104 (100.0)

Traditional Cropping System Awareness

Farmers' awareness of traditional cropping systems and their ecological functions is presented in Table 13. A very high proportion of respondents (95.2%) recognized that continuous monocropping of sorghum leads to soil fertility decline and reduced yields. This strong awareness reflects a clear experiential understanding of land degradation processes associated with repeated cultivation without restorative practices.

Approximately 69.2% of respondents acknowledged that intercropping sorghum with legumes improves soil fertility, reduces soil erosion, and minimizes pest and disease incidence. The same proportion recognized that crop rotation helps prevent soil fertility decline and enhances soil organic matter accumulation. Furthermore, 67.3% of respondents were aware that crop rotation disrupts pest and disease cycles, while a higher proportion (92.3%) understood its role in improving soil fertility through biological nitrogen fixation.

These findings demonstrate a strong alignment between indigenous knowledge and the scientific principles of sustainable cropping systems. Practices such as crop rotation and intercropping are well documented for their ability to enhance nutrient cycling, suppress pests and diseases, and stabilize yields, particularly in low-input agricultural systems (Altieri, 2002).

In contrast, awareness of agroforestry practices was relatively lower. Only 54.8% of respondents recognized that integrating trees or shrubs with crops improves soil quality by increasing organic matter and reducing erosion. This indicates a notable knowledge gap, despite extensive evidence supporting the role of agroforestry in enhancing soil fertility, improving ecosystem resilience, and mitigating land degradation (Nair, 2012). Strengthening farmer awareness and providing technical support for tree–crop integration could therefore significantly contribute to long-term soil sustainability in sorghum-based farming systems.

Conclusions

This study documented indigenous knowledge, traditional cropping systems, and soil fertility management practices among smallholder sorghum farmers in the Hararghe Zone of Oromia, Ethiopia. The findings demonstrate that sorghum production remains strongly embedded within locally developed knowledge systems shaped by farmers' long-term experience, environmental conditions, and livelihood needs.

Table 13

Traditional Cropping System Awareness

Statement	Recognized (%)	Not Recognized (%)	Total N (%)
Continuous cultivation of sorghum alone on a piece of land leads to soil degradation and reduction in yields.	99 (95.2)	5 (4.8)	104 (100.0)
Planting sorghum with other crops, such as legumes, on the same field improves soil fertility, prevents soil erosion, and reduces pests and diseases.	72 (69.2)	32 (30.8)	104 (100.0)
Alternating the cultivation of sorghum with other crops, such as legumes, roots, and tubers, helps prevent soil fertility decline and builds soil organic matter.	72 (69.2)	32 (30.8)	104 (100.0)
Indigenous knowledge of crop rotation helps break pest and disease cycles.	70 (67.3)	34 (32.7)	104 (100.0)
Indigenous knowledge of crop rotation helps fix nitrogen in the soil, thereby improving soil fertility.	96 (92.3)	8 (7.7)	104 (100.0)
Planting trees or shrubs alongside crops improves soil quality by increasing soil organic matter and reducing erosion.	57 (54.8)	47 (45.2)	104 (100.0)

Regarding indigenous knowledge and production practices, farmers maintained diverse sorghum production systems based on both improved varieties and local landraces, with farmer-saved seed serving as the dominant seed source. The continued use of local varieties, traditional seed selection, and indigenous storage practices highlights the importance of farmer-managed seed systems in conserving crop diversity and maintaining adaptation to local conditions.

Traditional cropping systems were characterized by crop rotation, intercropping, and monocropping, with crop rotation and sorghum–legume/cereal associations being the dominant practices. Farmers recognized the ecological benefits of these systems, particularly their contributions to soil fertility improvement, pest and disease management, erosion reduction, and production stability. These findings indicate strong alignment between indigenous agricultural knowledge and scientifically recognized principles of sustainable intensification.

The study also demonstrated that soil fertility management among sorghum farmers relies primarily on low-input, locally available practices, particularly animal manure application, crop rotation, composting, and residue management. Farmers showed high awareness of the benefits of organic amendments, conservation practices, and diversified cropping systems. However, a gap remains between knowledge and implementation for some practices, such as cover cropping, residue retention, and reduced soil disturbance, largely due to limitations in land availability, labor requirements, and access to resources.

Despite the ecological suitability and resilience of indigenous practices, their continued application is constrained by several factors, including limited access to agricultural inputs, pest and disease pressure, weak extension support, low mechanization, and declining transmission of traditional knowledge among younger generations. These challenges indicate that improving sorghum productivity requires more than introducing external technologies; it requires strengthening locally adapted practices through supportive institutions, improved input access, farmer training, and participatory extension approaches.

Overall, sorghum farming in Hararghe represents a multifunctional livelihood system that contributes to household food security, supplementary income, livestock production, seed conservation, and social exchange. Sustainable improvement of sorghum-based farming systems should therefore focus on integrating indigenous knowledge with appropriate scientific innovations rather than replacing traditional practices. Such an approach can enhance soil fertility, climate resilience, productivity, and the long-term sustainability of smallholder agriculture in semi-arid environments.

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Disclosure Statement

The authors declare that there are no conflicts of interest associated with this study.

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