Indigenous knowledge, diversity, and management practices of Ensete ventricosum (Welw.) Cheesman in Bita District, Southwestern Ethiopia: Implications for conservation and food security

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Indigenous knowledge, diversity, and management practices of *Ensete ventricosum* (Welw.) Cheesman in Bita District, Southwestern Ethiopia: Implications for conservation and food security

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Abstract

Background: Enset (*Ensete ventricosum* (Welw.) Cheeseman) is a vital staple crop in southern and southwestern Ethiopia, providing food, fiber, medicinal resources, and cultural value. Despite its importance, enset cultivation faces challenges including diseases, pests, decreasing land availability, and diminishing interest among younger generations. Documenting indigenous knowledge (IK) of enset cultivation is critical for preserving biodiversity, sustaining livelihoods, and ensuring food security.

Methods: A mixed-methods approach was employed, integrating household surveys (N = 204), key informant interviews, focus group discussions, and field observations. Data collection focused on enset propagation, planting patterns, fertilization, pest and disease management, harvesting, processing, and socio-cultural uses. Preference ranking and direct matrix ranking techniques were used to identify the most valued enset varieties, while statistical analyses in R software (version 4.4.3) examined the relationships between indigenous knowledge, age, gender, and education.

Results: Vegetative propagation via suckers was the dominant method, with farmers applying organic fertilizers and traditional pest management practices. Preference ranking indicated Nobo, Bejo, and Tayo as the most valued varieties based on food, fiber, and medicinal qualities. Direct matrix ranking highlighted multipurpose uses, reinforcing the socio-economic and cultural significance of enset. Age positively correlated with indigenous knowledge ($r = 0.634$, $p < 0.01$), while gender and literacy had no significant effect. Major threats included bacterial wilt (45.6%), mole rats (21.6%), and animal attacks (15.7%). Knowledge transfer from older to younger farmers emerged as a critical factor in sustaining cultivation practices.

Conclusion: Indigenous knowledge is central to the successful cultivation, management, and utilization of enset. Integrating traditional practices with modern interventions, promoting disease-resistant varieties, and engaging younger generations are essential to enhance productivity, maintain biodiversity, and secure food systems.

Keywords: *Ensete ventricosum*, indigenous knowledge, propagation, preference ranking, pest management, Ethiopia, food security.

Background

Indigenous communities have accumulated extensive knowledge of plants over centuries, encompassing their uses, conservation, and management for food, medicine, fodder, and other utilitarian purposes [1, 2, 3]. This traditional knowledge reflects the intricate interdependence between humans and ecosystems and forms the foundation for sustainable agricultural and natural resource management.

Enset (*Ensete ventricosum* (Welw.) Cheeseman), commonly known as "false banana," is a perennial monocarpic crop endemic to Ethiopia, serving as a staple food for over 20 million people, particularly in the southern and southwestern highlands [4, 5, 6]. Its cultivation is concentrated among ethnic groups such as the Gurage, Wolaita, and Sidama who have developed sophisticated indigenous knowledge systems related to landrace selection,

propagation, pest and disease management, and processing [7, 8, 9, 10]. Unlike banana (*Musa spp.*), enset is primarily cultivated for its starchy corm and pseudo-stem, which are processed into staple foods such as kocho, bulla, and amicho [11, 12, 13].

Despite its significance, enset cultivation faces numerous biotic and abiotic threats, including bacterial wilt (*Xanthomonas campestris* pv. *musacearum*), corm rot, sheath rot, and wildlife damage from mole rats, porcupines, and wild pigs [14, 15, 16, 17]. Environmental stresses, land-use changes, and the erosion of indigenous knowledge further exacerbate these challenges, threatening both crop diversity and food security [18, 19]. Traditional practices such as the selection of disease-resistant landraces, organic fertilization, intercropping, and locally adapted propagation techniques remain critical for sustaining productivity and resilience [13, 20].

Agricultural biodiversity and indigenous knowledge are pivotal for achieving sustainable food systems, resilient livelihoods, and environmental sustainability, directly contributing to SDG 2 (Zero Hunger), SDG 12 (Responsible Consumption and Production), and SDG 15 (Life on Land) [4, 21, 22, 23]. Enset cultivation supports household food security, buffers against climatic variability, and maintains socio-cultural practices, highlighting the intrinsic link between crop diversity, community resilience, and sustainable development [24, 25].

This study investigates indigenous knowledge, cultivation practices, and threats to *Ensete ventricosum* in Bita District, Kaffa Zone, Southwestern Ethiopia. Its objectives are to: (i) document indigenous knowledge and cultivation practices, including landrace selection, propagation, and processing; (ii) evaluate variations in cultivation practices across communities; (iii) identify biotic and abiotic threats to enset productivity; and (iv) assess the implications of cultivation changes for household and community food security.

The study is guided by the following hypotheses: (i) communities in Bita District possess indigenous knowledge crucial for maintaining enset biodiversity and food security; (ii) cultivation practices vary significantly with ethnicity, agroecology, and resource access; (iii) bacterial wilt and environmental stressors have reduced enset yield and diversity; (iv) and households maintaining diverse landraces and traditional practices achieve higher food security. By bridging indigenous knowledge with scientific inquiry, this research aims to provide a comprehensive understanding of enset cultivation in Bita District and develop culturally appropriate strategies for its conservation and sustainable utilization.

Materials and Methods

Description of the Study Area

The study was conducted in Bita District, Kaffa Zone, Southwestern Ethiopia. The district covers approximately 109,247 ha, representing 9.45% of the total area of Kaffa Zone. Its administrative center is Bita Genet, located about 523 km southwest of Addis Ababa. Bita is bordered by Sheka Zone to the west, Gesha to the north, Gaweta to the east, and Chena to the south. The district comprises 24 administrative kebeles, including Dacha, Ganit, Maligawi, and Woditi, with a total population of 101,386, of which 45% are male and 55% female [26]. The relatively higher proportion of women is notable, as women play a central role in enset cultivation and processing, which are vital for local food security and cultural identity.

Geographically, Bita District is characterized by sloping terrain, plateaus, rugged forested areas, and limited flatlands, creating a heterogeneous landscape. It lies between 7°12′33″ and 7°35′00″ N latitude and 30°29′15″–35°51′00″ E longitude, with an altitudinal range of 1200–2450 m a.s.l(Figure 1)[26]. The climate is marked by a unimodal rainfall pattern, with the main wet season from June to September (*Yooyo*, “summer” in the local language) and the dry season from December to April (*Biloo*, “winter”). According to data from the Ethiopian

National Meteorological Services Agency (2002–2022), the district receives an annual mean rainfall of 1526 mm. Average monthly temperature is 21.3°C, ranging from 13.1°C to 30.2°C, conditions that are particularly favorable for crops such as enset, which thrives in humid, temperate environments (Figure 2).

The natural vegetation is predominantly Afromontane forest, remaining green year-round. Characteristic plant species include *Cordia africana*, *Albizia gummifera*, *Eucalyptus globulus*, *Cyathea manniana*, *Dracaena afromontana*, *Millettia ferruginea*, *Pouteria adolfi-friedericii*, *Erythrina abyssinica*, *Ensete ventricosum*, and *Colocasia esculenta* [26, 27]. These species contribute to biodiversity, soil fertility, erosion control, and the supply of timber, fodder, and food. Enset plays a particularly important ecological role in soil conservation and water retention, while serving as the main staple crop that underpins food security and household economies in the district.

The area also supports diverse wildlife, including mantled guereza, civets, lions, and numerous bird and snake species [28]. These animals maintain ecological balance by dispersing seeds, controlling pests, and sustaining biodiversity. However, their coexistence with agricultural activities highlights the need for sustainable land-use practices. Agriculture is the primary livelihood in Bita, complemented by income-generating activities such as honey production, petty trade, and charcoal production. Farmers cultivate a wide range of crops, including cereals, pulses, vegetables, root and tuber crops, as well as permanent crops, ensuring diversified subsistence and cash income.

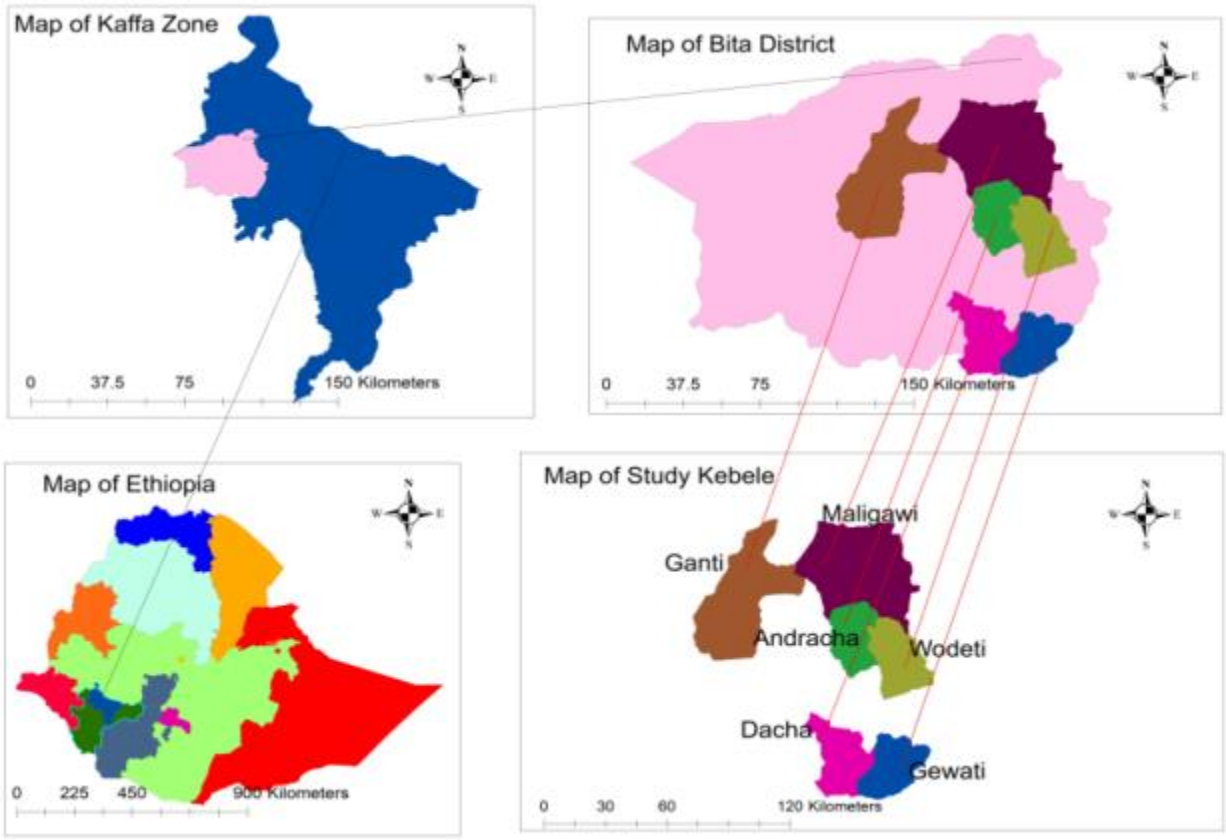

Figure 1. Map of the study area (generated using ArcGIS 10.4.1)

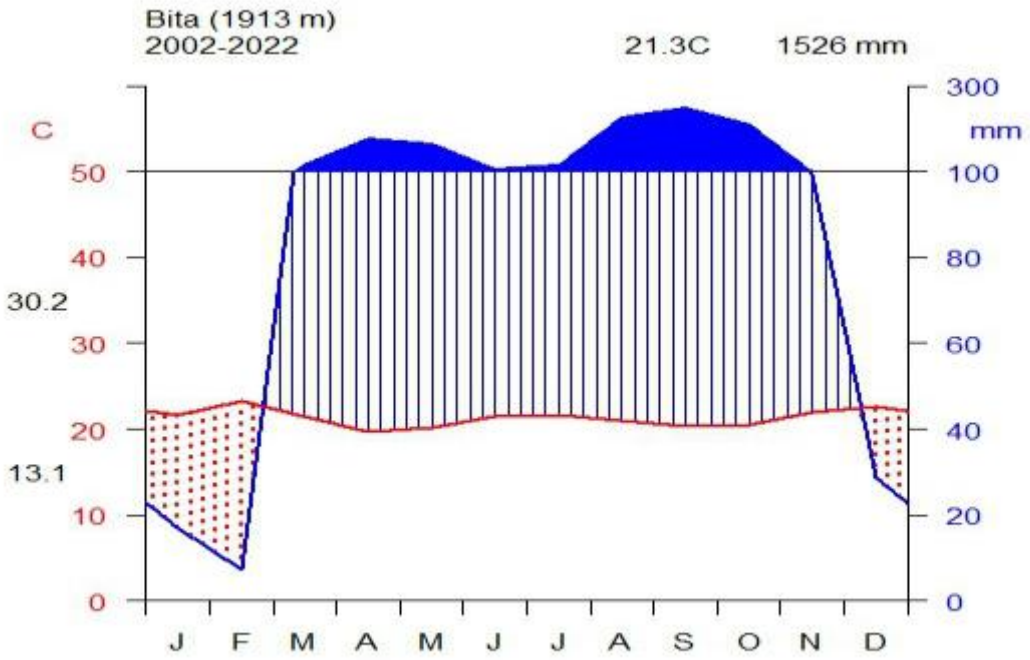

Figure 2. Climate diagram of the study area
(Data source: EMNSA, Shishinda Station). Note: Temperatures are indicated in °C (letter C). Red dots and the left vertical axis represent temperature variations, while blue lines and the right vertical axis indicate rainfall. The deep blue shading highlights the main rainy months.

Study Design

This study employed a descriptive research design to assess the diversity, threats, and indigenous management practices of *Ensete ventricosum* (Welw.) Cheesman in Bita District. The design enabled systematic observation and documentation of enset-related knowledge within the local community. It facilitated the collection of both qualitative and quantitative data through surveys and direct field observation, providing context-specific insights into current practices, challenges, and cultural significance. This approach was particularly appropriate for exploring under-researched topics, recording traditional practices, and generating baseline information to inform future interventions and conservation efforts.

Reconnaissance Survey, Informants, and Site Selection

A reconnaissance survey was conducted between September and October 2023 to identify potential study sites. Six kebeles: Ganit, Dacha, Anderacha, Gaweti, Woditi, and Maligawi were purposively selected from the 24 kebeles in

Bita District. The selection process involved consultations with local elders, administrative officials, and the rural development office, and was based on agricultural practices, agro-climatic conditions, vegetation cover, and accessibility. Formal permissions were obtained from relevant authorities, and prior informed consent was secured from local leaders and landowners in accordance with Ethiopian regulations governing plant research.

Key informants, including farmers, elders, and local experts, were identified during the survey to provide information on enset diversity, management, and cultural relevance. Their input also helped validate the suitability of the selected sites, ensuring representation of different agroecological zones and socio-cultural contexts. Enset's role as both a staple food and a food security reserve underscored the importance of selecting culturally and agriculturally significant sites [29].

Study Population and Sampling

The target population included agricultural experts, development agents (DAs), elders, and farmers with knowledge of enset varieties and management practices. Development agents were particularly valuable due to their close engagement with farmers and their role in documenting and disseminating agricultural knowledge [13].

A total of 204 informants were selected for the study, with 24 individuals from each kebele. Of these, 24 were identified as key informants through purposive sampling based on recommendations from DAs, kebele officials, and respected elders recognized for their expertise in enset cultivation. The remaining 180 general informants were recruited through snowball sampling. Informants ranged in age from 20 to 81 years, categorized into three groups: young adults (20–40 years), middle-aged adults (41–60 years), and elders (61–81 years). Elders were particularly important for transferring indigenous knowledge about enset diversity, threats, and management practices [13]

Four key informants were selected from each kebele based on criteria adapted from [1]. The selection process emphasized individuals with extensive experience in enset farming and management practices, as well as deep knowledge of local agricultural systems. Preference was also given to those recognized by the community as knowledgeable elders or experts, reflecting the cultural importance of traditional authority in agricultural decision-making.

In addition, efforts were made to ensure representation across different age groups, genders, and agroecological zones, thereby capturing diverse perspectives on enset cultivation and management. Farmers with long-standing involvement in enset farming and active engagement in indigenous management practices were prioritized. These informants provided both reliability and depth, serving as critical sources of qualitative and quantitative data for the study.

Ethnobotanical Data Collection

Ethnobotanical data were collected from December 2023 to February 2024 following the standard procedures outlined by [1]. The study aimed to document the diversity, threats, and indigenous management practices of *Ensete ventricosum* (Welw.) Cheesman within local communities. A range of tools was employed to enhance data accuracy and reliability. GPS devices were used to map locations of enset varieties and cultivation areas, while photographs and videos documented visual characteristics, cultivation practices, and management techniques. Audio recorders were employed during interviews to capture farmers' insights and traditional knowledge accurately. Data were organized, stored, and analyzed using both offline and online tools.

The study combined qualitative and quantitative methods to provide comprehensive insights. Structured and semi-structured interviews were conducted with farmers and key informants to collect detailed information on enset varieties, management practices, and threats. Questionnaires with both open- and closed-ended questions were

administered to quantify knowledge and practices. Focus group discussions (FGDs) were organized to capture shared community perspectives, while direct field observations provided practical verification of cultivation methods, environmental conditions, and challenges. Plant specimens collected during fieldwork were identified and verified with the assistance of botanists at the Botanical Gardens of Mizan Tepi University and Bonga University, supported by field photographs and reference materials.

Semi-structured Interviews

Semi-structured interview guides were prepared following [1]. These guides allowed flexibility to ask additional questions where necessary. Questionnaires were first developed in English and later translated into the local language, *Kafigna*. Informants were asked about local names of enset varieties, cultivation methods, indigenous management techniques, uses, drought tolerance, and crop diseases. Informed consent was obtained from all participants before interviews. Responses were categorized thematically into varieties, threats, and management practices. Qualitative findings were analyzed descriptively, while quantitative responses were processed using statistical methods to generate frequencies and percentages, with results presented in tables, charts, and graphs.

Focus Group Discussions

FGDs were held in each of the selected kebeles, involving 8–9 participants (Figure 3**)**. Discussions focused on local enset varieties, farmer-to-farmer material exchange, cultivation methods, harvesting times, and traditional practices transmitted across generations. A checklist of questions, prepared in English and translated into *Kafinoonoo*, guided the discussions. Key informants identified by local elders, administrators, and development agents participated, ensuring representation across gender and age groups. The FGDs facilitated interactive sharing of knowledge on threats and indigenous management strategies.

Figure 3. Group discussions with informants (photograph by researcher Kindu Chane)

Field Observations

Field observations provided first-hand data on enset cultivation, threats, and management. Observations focused on planting methods, soil conditions, pests, diseases, and indigenous practices. Data were recorded using field notes, photographs, and checklists (Figure 4**)**. This method also enabled estimation of land area under enset cultivation in both home gardens and farmland. Observations identified mature, flowering, and diseased varieties, complementing interview and questionnaire findings.

Figure 4. Field observation with informants (photograph by Kindu Chane)

Data Analysis

The collected data were compiled, coded, and analyzed using R software (version 4.4.3). Qualitative responses were organized into thematic categories, while quantitative data were processed to produce descriptive statistics, including frequencies and percentages. The results were presented through charts, graphs, and tables to highlight key patterns and reflect community perspectives.

Free Listing

Free listing was applied to document all local enset varieties, threats, and management practices mentioned by informants [30]. Participants were asked to list varieties they knew, along with their perceived uses and associated challenges. The compiled lists were analyzed to identify commonly recognized varieties and threats, providing insights into the richness of indigenous knowledge and informing subsequent quantitative analysis.

Preference Ranking

Twelve key informants were asked to rank enset varieties based on their usefulness for *kocho*, *bulla*, *amicho*, fiber, fodder, and medicinal purposes, following [1, 31]. A five-point scale (1 = lowest, 5 = highest) was used, with higher scores reflecting greater perceived utility. This method highlighted locally preferred varieties and the criteria underlying community valuation.

Direct Matrix Ranking

Direct matrix ranking was conducted following [1, 31] to compare the multipurpose uses of selected enset varieties. Five commonly cultivated varieties were evaluated across five use categories—food, medicine, fiber, fodder, and disease resistance. Five key informants assigned scores (1 = least useful to 5 = most useful). Mean scores were calculated for each use category, and total scores were used to rank the varieties, providing comparative insights into their multifunctional importance.

Ethical Considerations

The Bita District Administration Office provided official authorization for the study following a letter of collaboration from the Department of Biology, Mizan Tepi University. Permissions were secured before fieldwork commenced. The objectives of the study were explained to all participants, and oral informed consent was obtained prior to interviews and discussions. Participants were assured that the documentation of enset diversity, threats, and management practices was intended to support community benefits and promote sustainable use of this vital crop.

Results and Discussion

Varieties of *Ensete ventricosum* in the Study Area

The study documented 38 locally recognized landraces of *Ensete ventricosum* across the highland, midland, and lowland zones of Bita District, reflecting considerable on-farm diversity shaped by ecology and household needs. This figure is slightly lower than diversity reported in Sidama (52), Wolaita (55), Hadiya (59), and Sheka (66) [7, 9, 13, 20], yet consistent with clonally propagated crops where varietal counts are influenced by ecological variation, folk naming systems, and cultural preferences.

Farmers in Bita select varieties based on kocho yield, maturity, processing quality, drought tolerance, and resistance to disease. Prominent landraces include Achecho, Agen, Areko, Ateri, Beresho, Bocho, Bedado, Chele Bejo, Nache Bejo, Kekero, Nobo, Shalako, Kopier, and Shuri (Figure 5**)**. Local classification distinguishes male (*Anamo*) and female (*Mache*) types : late-maturing male varieties such as Gudiro and Nobo are valued for bulla, fiber, and kesho, while early-maturing female types like Adiyo, Echiwi, and Shuri are preferred for food and amicho. Although not biologically based, this functional taxonomy reliably guides cultivation and varietal management [30, 33].

Only about 16% of landraces were perceived as disease resistant, with Nobo standing out as particularly robust. This finding underscores the vulnerability of most varieties to enset bacterial wilt (EBW), caused by *Xanthomonas vasicola* pv. *musacearum*, Ethiopia's most serious enset constraint [34, 35, 36]. Similar to evidence from banana systems, integrated practices such as sanitation, tool sterilization, and synchronized rouging are recommended for EBW control [37, 38]. Other threats include plant-parasitic nematodes and microbial imbalances during kocho fermentation [39, 40]. Variation in pseudo-stem and leaf morphology also affects processing quality and fiber yield, underscoring the value of combining farmer knowledge with scientific evaluation in breeding and conservation [41].

Food remains the primary use of enset in Bita, while fiber, bulla, and kesho mainly from male varieties highlight its multifunctionality. Compositional studies support farmer perceptions of nutritional and quality differences among varieties [41, 42]. Early-maturing types are valued for food security, while late-maturing ones provide bulk biomass and fiber. This reflects household strategies of risk diversification, comparable to other perennial clonal crops [20, 43].

Although Ethiopia is the only country where enset is cultivated as a staple, wild relatives occur in neighboring countries, and ecological niche modeling suggests potential expansion into East and Southern Africa [44, 45, 46, 47]. For Bita, this global perspective highlights the demand for disease-resistant, high-quality clones and raises questions of equitable benefit-sharing if local landraces are incorporated into broader adaptation pipelines.

Three key insights emerge. First, Bita's "38-variety" (Table 1) portfolio represents a locally adapted strategy rather than a deficit [20]. Second, the *Anamo–Mache* system offers a practical framework for extension and breeding and should be formalized in agronomic descriptors [9]. Third, while the predominance of disease-susceptible varieties signals systemic vulnerability, farmer-identified tolerant landraces such as Nobo provide immediate candidates for participatory conservation and clonal multiplication [48].

Conservation strategies should integrate in situ management rooted in farmer knowledge with molecular characterization to resolve synonymy and identify rare or resistant landraces [33, 41]. Linking cultivated clones with wild germplasm from Uganda and beyond could strengthen pre-breeding for resistance and drought tolerance [44]. Locally adapted hygiene packages for EBW, improved nutrient management, and differentiated marketing of kocho and bulla products may further support resilience and livelihoods [37, 38, 42]. At a landscape scale, agroforestry integration and maintaining altitudinal redundancy will be critical under climate variability [45].

Reconciling vernacular classifications with molecular data is essential to minimize confusion and facilitate knowledge exchange across districts [33]. In addition, controlled phenotyping of resistance traits is required to verify farmer perceptions [37].

Figure 5. Selected enset (*Ensete ventricosum*) landraces (Photograph by Kindu Chane)

Table 1. Total Number of Enset Landraces per Household across Six Kebeles in the Study Area

Variety (Kf)	Type	DS	MA	PSC	Uses

Achacho	Female	No	3–4	Thin and medium in length	Food, fibers, leaves as mat
Agen	Female	No	4	Thin and short	Food (Amicho), leaves as mat and bread
Areko	Female	No	3	Thin and short but high production	Food (good for Amicho), fiber, leaves as mat
Ateri	Female	No	2–3	Thin and medium in length	Food (kocho and Amicho), fiber, leaves as mat
Adiyo	Female	No	>4	Pseudo-stem black, wide, thick, medium length	Food, leaves as bread, animal fodder
Bocho	Male	Yes	4	Thick, broad and long leaves	Food, fiber, Bulla, Amicho, leaves as bread & mat
Bedado	Male	No	4–5	Thick, long/short depending on environment	Food (kocho), fiber, Amicho, sweet, disease-tolerant
Chele Bejo	Male	Yes	>4	Red pseudo-stem and leaves, thick, medium length	Food, Kesho (Ersho), Bulla
Nache Bejo	Male	Yes	>4	White pseudo-stem and leaves, thick, medium length	Food, Kesho (Ersho), Bulla
Beresho	Female	No	3–4	Thin and short	Food, leaves as bread & fodder
Choro	Male	No	4	Thin, medium length	Food, medicinal, Amicho, leaves as mat
Echiwi/Mecho	Female	No	3–4	Thin and short	Food (Amicho), fiber, leaves as mat
Epo (Wild)	Male	No	>4	Thick, long	Leaves as bread, animal fodder
Genji	Female	No	4	Thin and short	Food, fiber, low production
Geyo	Female	No	3–4	Short and thin	Food, Amicho, leaves as fodder
Gosheno	Male	No	>4	Long and thick	Mainly used for Kesho (Ersho)
Gudero	Male	Yes	4–5	Thick, red, broad, medium length	Food
Kebo	Female	No	3–4	Medium and thin	Food, fiber, leaves as fodder & mat
Kekero	Female	No	3	Short and thin	Food (Amicho), fiber, leaves as bread & fodder
Kello	Female	No	3–4	Long and thick	Food, Amicho, leaves as mat
Kopier	Female	No	3–4	Red pseudo-stem and leaves, short, thin	Food, Amicho, leaves as mat & fodder
Mechadame	Female	No	4	Thin, medium length	Amicho production, medicinal value
Okero	Male	Yes	4–5	Thick, medium length	Food, fiber, leaves as mat, animal fodder
Nobo (Oldest)	Male	High	>4	Thick, long	Food (fibrous), Bulla (Ethino), fiber, leaves as mat

Shalako	Male	No	Up to 7	Very long and thick	Food, fiber, leaves as bread, mat, fodder
Shuri	Female	No	3	Thin and short	Food, fiber, medicinal, leaves as mat, shade & cattle birth aid
Tayo	Female	No	2–4	Very thin and long	Food, Bulla (Ethino), Amicho (Uto), fiber, leaves as mat, medicinal use
Utro	Female	No	3–4	Thin and short	Food, fiber, leaves as mat
Wango	Female	Yes	4	Medium thick and long	Food, fiber, leaves as mat
Wuo'o	Female	No	3	Short, broad leaves, thin	Food, fiber, leaves as mat
Ya Bejo	Male	Yes	>4	Medium thick, medium length	Food, fiber, leaves as bread & mat
Yeko	Female	No	3–4	Medium and thin	Food (sweet), fiber, leaves as mat

Key: Kf= Kafigna MA=Maturity Age (Years), **PSC=**Pseudo-stem/Leaf Characteristics, **DS=** Disease Resistance

Indigenous Knowledge on the Origin of Enset

The perception among the vast majority of respondents in Bita District (95.58%) that *Ensete ventricosum* originated locally and was passed down through ancestral heritage underscores the depth of cultural attachment community's hold toward the crop (Figure 6**)**. This belief system reflects not only the crop's role as a staple food but also its symbolic position as part of community identity and continuity across generations. Such perceptions are consistent with broader ethnobotanical evidence from southern Ethiopia, where enset is regarded as "the tree against hunger" and embedded within social, ritual, and spiritual life [33, 49, 50]. The small minority of respondents attributing enset's origin to divine creation or expressing uncertainty illustrates variation in cultural narratives, but the dominant ancestral framing highlights the intergenerational knowledge systems that sustain agrobiodiversity.

Ethiopia is globally recognized as a center of origin and diversification for several important crops, including sorghum (*Sorghum bicolor*), finger millet (*Eleusine coracana*), Niger seed (*Guizotia abyssinica*), and teff (*Eragrostis tef*) [50, 51, 52]. Within this context, enset occupies a unique niche as a vegetatively propagated perennial that has been domesticated from wild relatives native to the Ethiopian highlands [53, 54, 55]. Archaeological and historical evidence suggests that the domestication of enset may extend back 10,000 years, positioning it among the earliest cultivated plants in the region [56, 57,58]. This temporal depth, coupled with its remarkable resilience to drought and capacity to buffer seasonal food shortages, situates enset as both a biological and cultural keystone species in the Ethiopian highlands.

Comparative evidence from other countries demonstrates how cultural perceptions of crop origins play a central role in sustaining agrobiodiversity. For instance, in West Africa, yam (*Dioscorea spp.*) is often framed in mythological narratives that reinforce its status as both staple food and cultural heritage, strengthening conservation practices [59]. Similarly, in the Andes, potatoes (*Solanum tuberosum*) are viewed as ancestral gifts, and this perception underpins community-led conservation and the maintenance of thousands of local varieties [60]. In East and Central Africa, banana (*Musa spp.*) closely related to enset is embedded in oral histories that trace its origin to ancestral homelands, legitimizing its cultivation and ritual use [61]. These cross-cultural parallels emphasize that origin narratives are not merely symbolic but have practical implications for crop conservation, farmer selection, and resilience.

The Bita case illustrates how indigenous knowledge of enset's origin reinforces the perception of the crop as "ancestral property" to be safeguarded, thus strengthening community-led conservation. Such cultural framing can be leveraged in contemporary conservation strategies, especially as enset faces increasing threats from bacterial wilt and climate variability. Recognition of enset's origin in Ethiopia also has international implications: ecological niche modeling has demonstrated that vast areas of East and Southern Africa are suitable for enset cultivation, raising prospects for its expansion beyond Ethiopia as a climate-resilient crop [62]. In such a scenario, acknowledging and protecting the cultural and intellectual heritage of Ethiopian farmers will be essential to ensure equitable benefit-sharing and prevent the erosion of local custodianship.

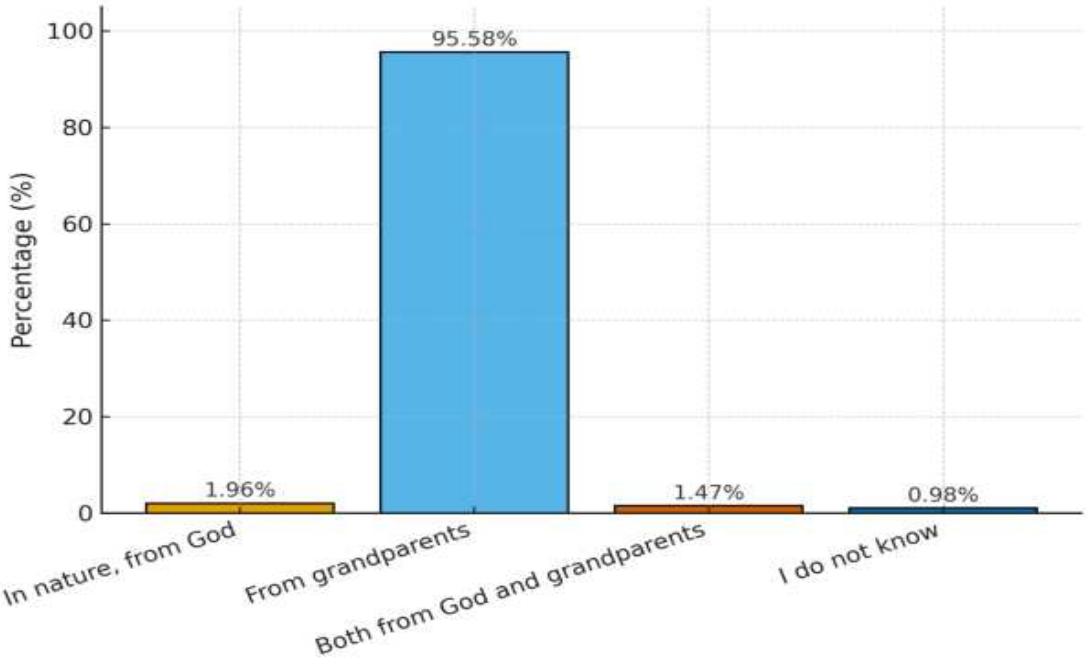

Figure 6. Indigenous knowledge regarding the origin of enset (*Ensete ventricosum*)

Selection of *Ensete ventricosum* Varieties

The findings from Bita District demonstrate that farmers' varietal selection of *Ensete ventricosum* is shaped by both agronomic considerations and cultural values, reflecting a sophisticated indigenous knowledge system. Disease resistance emerged as the most important criterion (34.8%), followed by plant size (27.45%) and taste (16.17%), with maturation period, leaf color, and plant shape considered secondary (Figure 7**)**. This prioritization reflects the dual pressures of ensuring food security and maintaining culinary and cultural quality. Farmers' emphasis on disease resistance is particularly significant given the prevalence of enset bacterial wilt (*Xanthomonas vasicola* pv. *musacearum*), which remains the most devastating threat to enset farming systems across Ethiopia [14, 63]. The identification and preferential cultivation of resistant landraces by farmers therefore aligns closely with scientific efforts to mitigate the crop's vulnerability and demonstrates the adaptive value of farmer-led selection practices.

The prioritization of plant size and biomass reflects the need for high yields of both food and fiber, echoing reports from Sidama, Wolaita, and Hadiya, where farmers consistently associate larger plant stature with greater kocho output and multipurpose value [7, 8, 9, 64]. Taste, meanwhile, is a strong determinant of varietal preference, consistent with consumer-driven selection patterns observed in Wolaita and Gurage, where palatability of kocho and bulla often determines market demand [7, 17]. The interplay of agronomic, culinary, and market-oriented criteria indicates that varietal selection is not a narrow process of maximizing yield but rather a holistic strategy to balance productivity, resilience, and cultural acceptability.

Comparative perspectives reveal that this multi-criteria selection system is not unique to enset but reflects a broader pattern observed in smallholder clonal crops worldwide. In the Andes, for example, farmers select potato (*Solanum tuberosum*) varieties based on disease tolerance, tuber size, taste, and cooking qualities, with cultural and ritual values often as decisive as agronomic ones (Brush, 2019). Similarly, in West Africa, yam (*Dioscorea spp.*) landraces are selected for resilience to pests, storability, and culinary texture, reflecting a balance of agronomic performance and food culture [59]. For banana in East Africa, farmers' choice of cultivars is shaped by resistance to banana Xanthomonas wilt, bunch size, and brewing or cooking qualities, highlighting parallels to enset's disease-yield-quality nexus [61]. These cross-cultural parallels illustrate how farmer-driven selection systems, grounded in indigenous knowledge, play a central role in sustaining crop diversity under smallholder management.

The distinction between "male" and "female" enset varieties reported in the study reflects an indigenous classification system with functional agronomic significance. While these categories do not correspond to biological sex, they guide management decisions by signaling maturity class, productivity, and end-use quality [7, 13]. This folk taxonomy mirrors farmer-led classification in other regions and crops, where symbolic categories encode important agronomic traits. By formalizing such systems into breeding descriptors, scientists can better align varietal evaluation with farmer priorities and ensure participatory approaches in conservation and improvement programs.

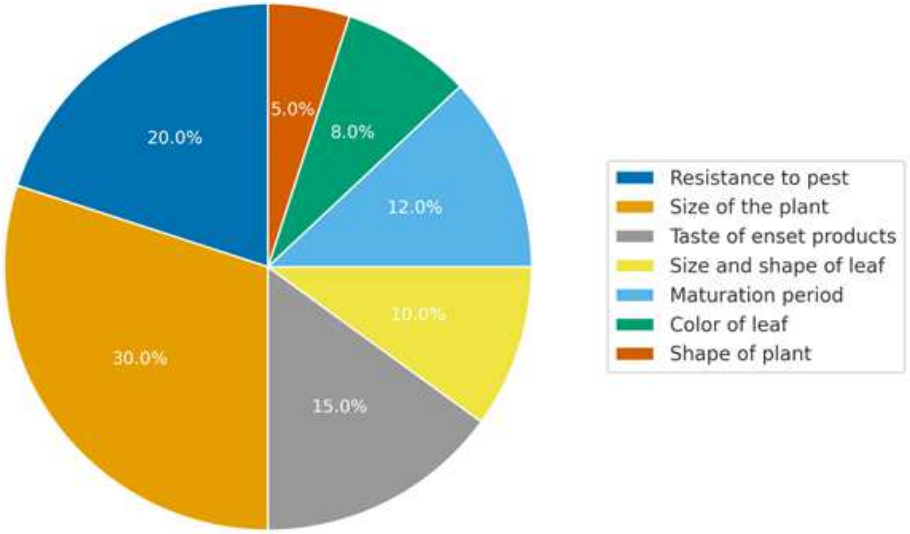

Figure 7. Farmers' criteria for selecting enset (*Ensete ventricosum*) varieties

Indigenous Knowledge of Enset Cultivation

The findings from Bita District reaffirm the centrality of *Ensete ventricosum* in rural livelihoods, where it functions not only as a staple food but also as a source of income, cultural identity, and ecosystem services. The majority of farmers cultivate enset as a monocrop (57.07%), while others integrate it into home gardens and main fields (21.07%), demonstrating the crop's versatility within different production systems(Figure 8**)**. This dual cultivation

pattern is consistent with previous reports from southern Ethiopia, where enset is often grown in concentric homestead gardens for food security, while larger plots are maintained for surplus production and market-oriented purposes [15, 18]. The persistence of such practices underscores the role of enset as both a subsistence and commercial crop, intricately linked with household survival strategies.

The emphasis of elder participants on the cultural significance of enset resonates with earlier ethnographic research in the Kafa–Sheka, Sidama, and Gurage regions, where enset cultivation is strongly embedded in ritual practices, community identity, and intergenerational knowledge transfer [7, 9, 10, 13, 65, 66]. This cultural embeddedness not only strengthens the social fabric but also ensures the continuity of traditional knowledge systems that sustain agrobiodiversity. Such indigenous knowledge encompasses not only cultivation but also post-harvest processing, preservation, and food preparation techniques that contribute to enset's unique resilience as a perennial staple.

The reliance on natural soil fertility management practices, including the use of manure, crop residues, and intercropping, highlights farmers' ecological knowledge and their ability to sustain productivity without extensive reliance on external inputs. This aligns with broader agroecological findings from Ethiopia, where resource-poor farmers employ traditional organic methods to maintain soil fertility and enhance resilience under climate variability [67, 68]. Comparable practices are also evident in other smallholder systems globally. For instance, Andean farmers managing potato landraces rely on organic amendments and intercropping for soil health [69], while West African yam farmers integrate organic residues and crop rotations for long-term productivity[70]. These parallels underscore the global relevance of indigenous soil fertility management in sustaining clonal and perennial crops.

The predominance of monocropping reported in this study raises important questions regarding agroecological sustainability. While monocropping facilitates easier management and maximization of yield per unit area, it may also increase vulnerability to pests and diseases such as bacterial wilt (*Xanthomonas vasicola* pv. *musacearum*) [71]. In contrast, intercropping systems observed in some farms provide ecological buffering, supporting nutrient cycling, microclimatic regulation, and pest suppression. This suggests that promoting diversified cropping systems that integrate enset with cereals, legumes, or perennial trees could enhance both productivity and resilience, a principle widely demonstrated in agroforestry-based enset systems in Sidama and Wolaita [7, 32].

From a comparative perspective, the multifunctional role of enset in Bita District mirrors other perennial staples cultivated under traditional management worldwide. For example, banana in East Africa is central to food security, culture, and income, while its cultivation systems are similarly shaped by indigenous ecological practices [72]. In the Andes, potato systems exemplify how traditional knowledge maintains crop diversity and cultural identity while simultaneously buffering households against climatic and economic risks [73, 74]. These parallels reinforce the view that indigenous knowledge is not merely supplementary but fundamental to the conservation and improvement of staple crops under smallholder conditions.

a. Home garden b. Main field

Figure 8. Enset (*Ensete ventricosum*) cultivation in the study area: (a) home garden, (b) main field. Photograph by Kindu Chane

Size of Land Occupied by Enset Farms

The finding that all households in the study area cultivate enset on relatively small plots, ranging from 0.125 to 1.00 hectares with a mean of 0.562 hectares, reflects both the centrality of the crop in household subsistence and the growing challenges posed by land fragmentation. This average size is consistent with broader evidence across southern Ethiopia, where enset is typically cultivated on smallholder plots ranging from 0.25 to 0.75 hectares [75, 76]. The reduction in land allocated to enset over time is a matter of concern, as the crop requires long maturation cycles and benefits from stable, larger areas that allow intergenerational transmission of indigenous knowledge and varietal diversity.

Elder participants' concern that shrinking farm sizes could erode indigenous knowledge highlights the intrinsic link between land availability and cultural continuity. As farms diminish, farmers may prioritize short-cycle crops such as maize or teff over enset, which takes 4–7 years to mature. This shift may compromise both dietary diversity and cultural practices associated with enset processing, ceremonies, and community leadership, echoing earlier findings in Sidama and Gurage zones where reduced enset cultivation led to a weakening of traditional management systems [64, 77].

The decline in enset cultivation area from approximately 16% of cultivated land in the 1960s to 8% in the current study area illustrates the long-term pressures facing the crop. These pressures stem not only from population growth and land subdivision due to inheritance practices but also from broader structural transformations in Ethiopian agriculture, including commercialization of cereals and expansion of cash crops such as coffee and khat [78, 79]. Similar processes of land-use change have been reported in other indigenous farming systems globally. For instance, in the Andean highlands, potato plots have diminished due to market-driven expansion of quinoa and barley, with direct consequences for agrobiodiversity and local food traditions [74]. Likewise, in Uganda and Rwanda, banana cultivation faces spatial decline due to urbanization and cash crop expansion, threatening long-standing cultural and nutritional roles of the crop [80, 81]. These parallels emphasize that the erosion of staple crop cultivation areas under land pressure is not unique to Ethiopia but part of a broader global challenge affecting indigenous crops.

The implications of shrinking enset farm sizes are multifaceted. From a food security perspective, reduced cultivation area directly limits household access to kocho, bulla, and amicho, thereby narrowing dietary options and heightening vulnerability to food shortages during lean seasons. This risk is particularly critical given enset's unique role as a "food security crop" that buffers against famine in southern Ethiopia [82, 83]. From an ecological standpoint, smaller enset plots constrain the capacity of farmers to maintain diverse landraces, undermining in situ conservation of genetic resources vital for climate adaptation and disease resistance. Moreover, as highlighted by participants, the erosion of land area poses a cultural threat: if fewer households sustain enset plots, indigenous knowledge systems surrounding soil fertility management, disease control, and varietal classification may be gradually lost.

Globally, successful models of land management for traditional crops suggest potential pathways forward. In the Andes, community-based land sharing and rotational systems have been used to sustain potato diversity under land scarcity [69]. In West Africa, farmer cooperatives play a role in preserving yam cultivation despite fragmentation pressures [59]. Similar collective approaches such as land-use planning at community levels, integration of enset into agroforestry systems, and targeted support for enset-based livelihoods could strengthen resilience in Ethiopia.

Planting Pattern of *Ensete ventricosum*

The predominance of scattered or non-row planting (77.94%) among farmers in the study area reflects a deeply embedded indigenous system of crop establishment, shaped by both ecological adaptation and cultural tradition. This practice is consistent with earlier reports from southern Ethiopia, where enset has historically been planted in irregular arrangements within home gardens to maximize space, conserve soil moisture, and integrate with other crops in diverse agroforestry systems [7, 79]. Although row planting was practiced by only 6.37% of respondents, this low adoption rate highlights the limited influence of formal agronomic extension services compared to local knowledge systems in guiding planting practices.

The ecological advantages of traditional dense and scattered planting patterns are noteworthy. The broad leaf canopy of enset provides natural mulching that reduces soil erosion, lowers surface temperature, and enhances water retention functions particularly vital in Ethiopia's drought-prone highlands. Similar ecological services have been observed in banana and plantain systems in East and Central Africa, where dense planting helps maintain soil fertility and microclimate stability, although excessive density can suppress plant vigor [71, 84]. In the Andes, potato and quinoa are likewise cultivated in irregular and polycultural systems, where dense or scattered planting patterns are employed to reduce pest incidence, improve resilience, and optimize use of marginal lands [74]. These parallels suggest that Ethiopian farmers' planting strategies are part of a broader global repertoire of indigenous agroecological practices designed to maximize resilience under land and climate constraints.

Nonetheless, certain drawbacks of unstructured planting must be acknowledged. The survey results and field observations revealed that stunted or underdeveloped enset plants are common outcomes of dense initial planting followed by selective thinning. While this method ensures that only vigorous plants are retained, it also indicates resource competition in the early growth stages. Studies in Wolaita and Sidama have similarly reported that dense planting without standardized spacing reduces biomass accumulation and can increase susceptibility to bacterial wilt (*Xanthomonas campestris* pv. *musacearum*) due to poor air circulation [33, 85]. In contrast, systematic row planting though rarely practiced has been shown in experimental trials to improve growth uniformity, facilitate disease monitoring, and enhance yields when combined with organic soil amendments [86, 87].

From a socio-cultural perspective, the reliance on indigenous spacing practices underscores the importance of knowledge passed down through generations, which considers soil fertility, topography, and household needs rather than externally imposed agronomic prescriptions. This resonates with experiences in other indigenous crop systems: for example, yam cultivation in West Africa follows non-row planting based on traditional soil fertility indicators, while taro cultivation in Pacific islands employs pit planting enriched with compost, mirroring enset practices [59, 88]. These global parallels highlight how localized knowledge systems have developed complex strategies to balance productivity with ecological sustainability.

Transplanting of Enset Suckers

The practice of transplanting enset suckers (*Ukkoo*) approximately one year after planting, as observed in the study area, highlights the central role of vegetative propagation in sustaining enset-based farming systems (Figure 9). This practice, combined with leaf and top trimming to stimulate regeneration, has long been recognized as a hallmark of indigenous enset cultivation in Ethiopia [89, 90]. The predominance of early rainy season transplantation (March-April), followed by flexible adjustments in planting time depending on local agroecological conditions, demonstrates a nuanced synchronization of crop management with seasonal climatic patterns. Such timing reflects an adaptive strategy aimed at maximizing sucker survival, establishment, and subsequent growth under variable rainfall regimes.

These findings align with broader experiences across Ethiopia, where sucker movement is not only a technical step in propagation but also a culturally embedded practice. In Sidama, Gurage, and Wolaita, farmers similarly transplant suckers at the onset of rains, using animal manure and compost to enrich soils, and adjusting plant spacing based on soil fertility and anticipated yields [9, 17, 31]. This flexibility mirrors adaptive planting systems in other perennial root and tuber crops. For instance, banana and plantain farmers in Uganda and Kenya also rely on vegetative propagation through sucker transplantation, with timing closely aligned to rainfall onset to ensure establishment [91, 92]. Likewise, in West African yam cultivation, minisett or sucker-like vegetative propagules are transplanted after initial sprouting, with variations in timing based on agroecological zones [59]. These cross-cultural comparisons underscore that vegetative propagation systems often depend on intimate knowledge of local rainfall cycles, soil fertility, and ecological conditions, integrating environmental adaptation with generational experience.

The trimming of sucker leaves and tops prior to transplantation, as practiced in Ethiopia, represents a further innovation in vegetative propagation. Farmers believe this reduces transplant shock and enhances rooting, an interpretation consistent with physiological studies that show reduced transpiration and energy allocation toward shoot growth can improve root establishment [90]. Comparable practices are reported in taro (*Colocasia esculenta*) cultivation in Pacific islands, where trimming of leaves prior to replanting enhances water-use efficiency and reduces wilting during establishment [69, 93]. Similarly, cassava farmers in Latin America often prune cuttings before planting to minimize desiccation stress [71, 94]. These parallels demonstrate that Ethiopian enset farmers' practices are part of a globally shared repertoire of vegetative propagation strategies designed to improve establishment and resilience.

a. Corm /mother enset plant b. Suckers (uukko) c. One year old

d. Two years old e. Three years old f. Four years old

g. Five years old h. Well matured i. Post-harvest/end of cycle

Figure 9. Indigenous enset (*Ensete ventricosum*) development cycle in the study area: (a) corm/mother plant, (b) suckers (uukko), (c) one year old, (d) two years old, (e) three years old, (f) four years old, (g) five years old, (h) well-matured, (i) post-harvest/end of cycle

Land Preparation, Weeding, Leaf Pruning, and Tools

The findings on land preparation, weeding, leaf pruning, and the use of traditional tools in enset (*Ensete ventricosum*) cultivation highlight the intricate relationship between indigenous knowledge, ecological adaptation, and cultural heritage. Farmers in the study area, as in other enset-growing regions of Ethiopia, rely on site clearing, plowing, and incorporation of organic matter to enhance soil fertility, thereby creating optimal growing conditions [7, 65]. These practices reflect a longstanding adaptation to the highland agroecological system, where soil fertility and structure determine the productivity of perennial crops such as enset.

The emphasis on organic fertilization using manure and compost illustrates a sustainable approach that maintains soil health and productivity over generations. This resonates with practices observed in Sidama, Wolaita, and Gurage, where manure application is not only a fertility-enhancing measure but also a means of recycling farm by-products, thereby reinforcing circular farming systems [7, 9, 31]. Comparable approaches are documented in smallholder banana systems in Uganda and Rwanda, where composting and mulching are routinely used to sustain soil fertility and moisture [71]. Similarly, Andean farmers cultivating potatoes employ traditional manuring and organic matter incorporation to restore soil productivity under continuous use [69, 95]. Such cross-cultural parallels underscore the universality of organic inputs as cornerstones of resilient, low-external-input farming systems.

Weeding emerged as another critical management practice. In Ethiopia, manual weeding using hoes or hand-pulling remains the dominant approach, particularly during the rainy season when weed pressure is highest [18]. This aligns with findings in perennial cropping systems elsewhere, where labor-intensive weeding is essential to reduce competition for resources. For example, in banana plantations of East Africa, farmers routinely weed manually during the wet season, as chemical herbicides are less accessible and often considered detrimental to soil health [37, 72]. Likewise, yam growers in West Africa integrate periodic hand-weeding into their crop management cycles to ensure robust growth [59]. These similarities demonstrate that manual weed control remains a critical but labor-intensive practice in smallholder systems globally, often requiring innovations to reduce drudgery while sustaining ecological benefits.

Leaf pruning in enset cultivation, reported by farmers in the study area, is not only a management tool to stimulate new growth but also a means of controlling plant vigor, supporting aeration, and facilitating disease management [13, 43]. Similar pruning practices are employed in other vegetatively propagated crops. For instance, cassava farmers in Latin America prune leaves to manage canopy growth and optimize light interception [94], while banana growers in Uganda and Tanzania remove old or infected leaves to minimize the spread of foliar diseases and enhance photosynthetic efficiency [59, 61, 91]. These parallels suggest that leaf pruning, though often underappreciated, constitutes a vital cultural practice that links plant physiology to long-term resilience and productivity.

The reliance on traditional tools such as machetes, hoes, spades, and pruning shears reflects both technological continuity and adaptation to local conditions. Tools like the *Gejero* (machete) and *Aganito* (hoe) remain indispensable due to their affordability, multifunctionality, and cultural familiarity (Figure 10). Similar reliance on simple yet versatile hand tools is evident among smallholder farmers cultivating taro in Pacific islands [88] and potatoes in the Andes [74]. However, limited mechanization may also constrain labor efficiency, particularly as rural labor availability declines due to migration and urbanization. Integrating improved, labor-saving tools with indigenous systems could therefore enhance sustainability without eroding traditional practices.

Figure 10. Traditional tools used for enset (*Ensete ventricosum*) cultivation in the study area

Indigenous Knowledge of Fertilizer Management Practices

The findings highlight the central role of indigenous knowledge in sustaining soil fertility and enset (*Ensete ventricosum*) productivity through organic fertilization. Farmers in the study area consistently reported year-round application of animal manure, with higher inputs during the dry season, emphasizing its essential contribution to both crop yield and human sustenance. The pervasive reliance on organic manure reflects a deep-seated understanding of nutrient cycling and soil health, integrated with traditional livestock management practices. This observation aligns with previous studies in Sidama, Gurage, Sheka, and Kaffa zones, where enset fields are strategically located near livestock to facilitate natural manure deposition [7, 9, 13, 97] .

The indigenous practices documented in Bita District illustrate several ecological and agronomic principles. First, the differential application of manure according to plant age and seasonal cycles demonstrates an adaptive approach to nutrient management. Younger enset plants receive proportionally more organic inputs during dry months (December–April), reflecting farmers' empirical knowledge of nutrient demand and soil moisture constraints. The staged decomposition of manure, from initial piling to gradual spreading around plant bases, further indicates careful timing to maximize nutrient availability while preventing root damage. These practices mirror findings in other Ethiopian highlands, where perennial crop systems rely on integrated organic inputs for sustained productivity [13, 97].

Gender-specific expertise also emerges as an important aspect of indigenous fertilizer management. Female farmers, often more involved in animal husbandry, are perceived to possess superior skill in preparing and applying compost and straw residues. This observation resonates with broader evidence from smallholder systems in sub-Saharan Africa, where women frequently manage organic amendments and soil fertility practices, contributing to both household food security and ecological stewardship [98, 99].

The exclusive reliance on organic manure, coupled with avoidance of synthetic fertilizers, has both ecological and cultural significance. Farmers believe that chemical inputs may reduce the nutritional quality of enset and even impact human longevity. While these beliefs are culturally embedded, emerging research confirms that long-term use of organic amendments in perennial cropping systems maintains soil organic matter, enhances microbial activity, and improves water-holding capacity [100, 101]. This highlights the convergence between empirical

indigenous knowledge and scientific evidence, suggesting that traditional manure application not only sustains yields but also preserves soil health over decades.

Globally, similar practices are observed in other perennial and agroecological systems. In Andean potato and quinoa fields, farmers integrate livestock manure into cropping systems, strategically applying compost to maintain soil fertility under steep, erosion-prone landscapes [74]. Likewise, in smallholder banana systems in Uganda and Rwanda, organic amendments remain central to productivity and environmental resilience, especially where access to synthetic fertilizers is limited or ecologically undesirable [61, 80]. These parallels underscore the global relevance of indigenous fertilizer management as a low-input, sustainable strategy compatible with climate-resilient agriculture.

Maturity, Harvesting, and Storage of Enset

Enset (*Ensete ventricosum*), often termed "false banana," occupies a unique role in Ethiopia as a staple crop that intertwines food security, cultural heritage, and agroecological sustainability. The findings indicate that farmers rely on a combination of tactile, visual, and experiential indicators to assess enset maturity, including pseudo-stem size and firmness, leaf coloration, and corm development. This knowledge, passed down through generations, reflects a sophisticated understanding of plant physiology and phenology, which has increasingly integrated modern agronomic insights to optimize harvest timing and yield prediction [9, 50].

The study shows that the majority of enset plants are harvested at four to five years, reflecting a balance between maximizing yield and maintaining quality for key products such as kocho, bulla, and fiber. Premature harvesting is largely avoided, demonstrating farmers' awareness of the negative consequences on both nutrition and market value. This aligns with prior research in highland and midland Ethiopia, where delayed harvest correlates with higher starch content, improved processing efficiency, and prolonged storage life [7, 8, 9, 13]. Variations in maturation age between ecological zones such as accelerated pre-maturity in lowlands at two to three years highlight farmers' ability to adapt harvesting strategies to local environmental conditions.

Cultural dimensions of enset harvesting are equally significant. Harvest events are often embedded in communal practices and rituals, emphasizing social cohesion and identity. These observations underscore the dual role of enset as both a food source and a cultural anchor, a feature that distinguishes it from many other staple crops globally [9].

Post-harvest management practices, particularly storage of processed products like kocho and bulla in shaded, ventilated areas, further reflect indigenous strategies to ensure year-round food security. Such practices maintain the biochemical integrity of enset, prevent spoilage, and extend shelf life, illustrating the integration of traditional knowledge with post-harvest science. Comparable storage strategies are documented in other perennial root and starch crops worldwide. For example, in Andean potato and cassava systems, farmers employ similar low-tech methods such as pit or cool, shaded storage to prolong edibility and nutritional value, particularly in resource-limited settings [74, 102].

Processing of Enset Products for Consumption

Enset (*Ensete ventricosum*) processing is a cornerstone of food security and livelihood strategies in southern Ethiopia, integrating complex indigenous knowledge with labor-intensive practices. The study highlights the sequential processing steps scraping pseudostems and corms with traditional tools such as the "Meto," chopping with a "Mero," fermenting in a "Tubumito," and pressing using a "Sheko" which collectively transform raw plant material into staple foods like kocho, bulla, and amicho (Figure 11). These steps not only maximize the nutritional

yield of enset but also ensure long-term preservation, aligning with prior research documenting the intricate indigenous techniques employed across Sidama, Gurage, Wolaita, and Kaffa areas [7, 9, 31].

The gendered nature of enset processing is particularly noteworthy. Women play a central role in harvesting, fermenting, and preparing enset products, reflecting entrenched sociocultural norms in Ethiopian agroecosystems. This mirrors patterns observed in other root and starch-based crop systems worldwide, such as cassava processing in West Africa and taro in the Pacific Islands, where female labor is pivotal for household food security and income generation [103, 104]. The Ethiopian context further emphasizes the dual role of women's labor: sustaining daily household nutrition and contributing to local economies through the sale of processed products.

Fermentation is a critical step, not only for converting corm and pseudostem material into edible forms but also for enhancing nutritional value, improving digestibility, and prolonging shelf life. Kocho, the fermented pseudostem product, serves as a staple consumed multiple times daily, while bulla, a refined starch obtained from mature plants, represents the highest-quality product in terms of nutrition and market value. Amicho, the boiled corm of young plants, is particularly prized for taste and texture. These differentiated product types reflect a sophisticated understanding of plant physiology, fermentation dynamics, and local dietary needs. Similar practices are reported in cassava-based systems in Nigeria and Uganda, where fermentation and starch extraction are tailored to optimize both sensory and nutritional outcomes [105].

Figure 11. Processing procedures of enset (*Ensete ventricosum*) products in the study area: (A) selection of matured plants, (B) cutting and separation of plant body, (C) chopping, (D & E) processing of kocho and storage in enset pits, (F) preparation of a dug well, long-term storage

Traditional Tools Used for Processing Enset Products

Enset (*Ensete ventricosum*) processing in Ethiopia remains deeply rooted in indigenous knowledge, with women at the forefront of employing traditional tools to convert raw plants into staple foods such as kocho and bulla. Tools including the "*Meto*" for scraping, the "*Mero*" for chopping, the "*Tubumito*" for fermenting, and the "Sheko" for pressing reflect not only technical functionality but also the cumulative cultural knowledge of generations (Figure 12). These implements facilitate efficient extraction and fermentation processes while sustaining household food security, illustrating the intersection of gendered labor, skill acquisition, and cultural continuity [4, 63].

The persistence of traditional processing tools across Ethiopia underscores both their effectiveness and the challenges they pose in terms of labor intensity and time demand. Comparative studies in Sidama, West Shewa, Gedeo, and Gurage zones reveal similar equipment: wooden boards such as Watani and Meta, split bamboo implements like Sisa, and iron knives or Cheko variants are widely used to process pseudostems and corms [8, 77,

78, 106]. Despite differences in design and material, these tools share a common functional goal: transforming enset into durable, edible products while maintaining nutritional quality and cultural authenticity.

Globally, parallels can be drawn with other root and starch-based crop processing systems, where traditional implements remain central to food security. For example, cassava fermentation in West Africa and taro processing in the Pacific Islands rely on wooden boards, knives, and pounding tools operated predominantly by women [93, 94, 105]. These cross-cultural comparisons highlight the broader relevance of gendered labor and indigenous tool use in sustaining rural livelihoods, while also signaling potential avenues for technological innovation.

A.  B 

C.  D. 

Figure 12. Traditional tools used for processing enset (*Ensete ventricosum*) products in the study area: (A) Meto, (B) Mero, (C) Tubo mito, (D) Sheko

Socio-Cultural Use of Enset

Enset (*Ensete ventricosum*) is not only a staple food in southern Ethiopia but also a cornerstone of socio-cultural identity, shaping rituals, communal labor systems, and traditional knowledge networks. The use of enset-based products such as kocho and bulla during weddings, festivals, and communal gatherings exemplifies its symbolic association with abundance, hospitality, and social cohesion [20]. These practices reinforce communal bonds through reciprocal labor systems, where neighbors assist in planting, harvesting, and processing, reflecting a deep intertwining of agricultural activity with cultural norms and ethical values. Specific enset varieties reserved for ceremonial purposes further highlight the crop's symbolic and cultural significance, with gifting of enset during life events signifying respect, unity, and shared heritage [10].

The multifunctionality of enset extends beyond cultural symbolism. Indigenous farmers report using enset primarily for human consumption (61%), followed by animal feed (16%), medicinal applications (13%), and other purposes (10%) such as rope, mats, and soil conservation(Figure 13) [13, 66]. Every part of the plant is harnessed, demonstrating its integral role in sustaining livelihoods. Medicinal uses, such as varieties employed to manage back pain or reproductive health issues, underscore the intersection of nutrition and traditional healthcare, aligning with reports from the Sheka and Gurage zones, where enset forms both a dietary and therapeutic resource [13, 17, 77]. The crop's perennial, drought-tolerant nature further distinguishes it from annual tubers, offering reliable food security and soil fertility maintenance in climatically vulnerable regions.

Comparative perspectives indicate that the socio-cultural embeddedness of staple crops is not unique to Ethiopia. Globally, root and tuber crops such as cassava in West Africa, taro in the Pacific Islands, and yam in parts of Latin America similarly support social rituals, community labor systems, and traditional medicine [59, 93]. Like enset, these crops function as cultural keystones, linking agricultural productivity to social cohesion and local identity. Such cross-cultural comparisons emphasize that the nutritional, economic, and cultural roles of perennial root crops often converge, reinforcing their value in food security and cultural resilience.

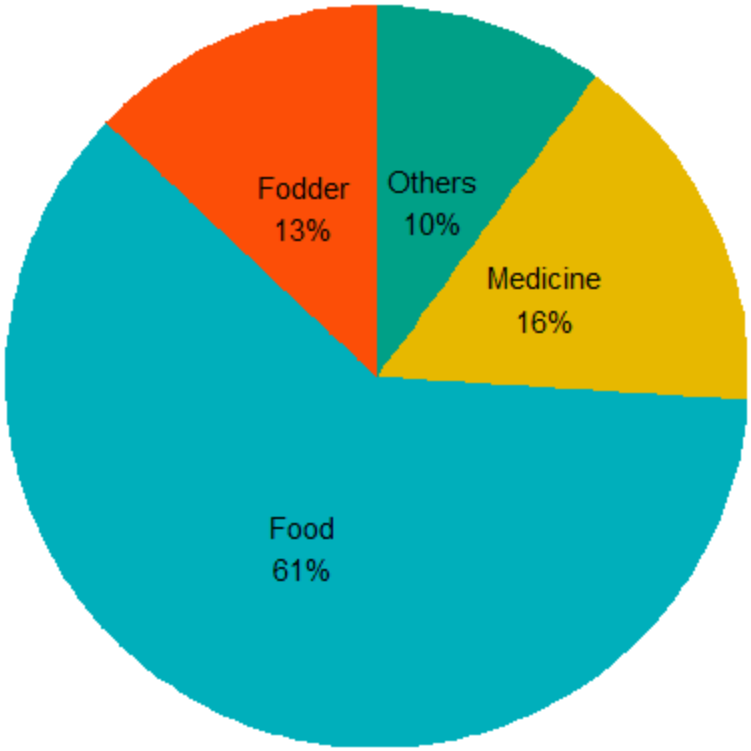

Figure 13. Traditional uses of enset (*Ensete ventricosum*) in the study area

Comparison of Indigenous Knowledge among Informant Groups

This study underscores the pivotal role of indigenous knowledge in the cultivation, management, and utilization of enset (*Ensete ventricosum*) in southern Ethiopia. Despite 62.25% of household heads being illiterate, formal education did not significantly influence enset-related practices (Table 2). In fact, illiterate households demonstrated a stronger understanding of enset diversity, threats, and management strategies than their literate counterparts, highlighting the centrality of experiential knowledge in sustaining agrobiodiversity and food security [13, 33]. This aligns with broader ethnobotanical evidence showing that traditional knowledge often surpasses formal education in effectively managing local crop diversity, particularly for under-researched species [26, 107].

Gender did not significantly affect indigenous knowledge scores. Both male- and female-headed households demonstrated comparable levels of expertise, reflecting the inclusive and shared nature of knowledge transmission

within enset farming systems [108, 109, 110]. In contrast, age emerged as a strong determinant: knowledge scores increased progressively from younger adults (under 40 years) to older adults (above 60 years), confirming the cumulative role of experiential learning. Similar patterns have been reported in other root and tuber systems, such as yam in West Africa and taro in the Pacific, where elders serve as custodians of varietal diversity, processing techniques, and ecological management [59, 70].

Quantitative analysis reinforced these findings. Among 204 households, 66.6% were male-headed and 33.3% female-headed, with no significant gender differences in knowledge (males: mean = 5.1, SD = 2.3; females: mean = 5.06, SD = 2.2; $p = 0.89$). However, literacy had a marked effect: illiterate respondents scored significantly higher (mean = 5.9, SD = 2.0) than literate ones (mean = 4.4, SD = 1.9; $t = 5.7$, $p < 0.05$). Age effects were also significant ($F(2, 201) = 12.94$, $p < 0.001$), with mean knowledge scores rising from 3.73 in younger adults to 5.92 in middle-aged adults and 8.02 in older adults (Table 3). A strong positive correlation was observed between age and knowledge of enset varieties ($r = 0.634$, $p = 0.000$).

The generational knowledge gap poses challenges for the sustainability of enset cultivation. Younger participants exhibited limited understanding, likely due to urban migration, changing livelihoods, and declining participation in traditional farming. Without active transfer, this threatens the continuity of indigenous practices, varietal preservation, and local food security. Strategies such as mentorship programs, participatory training, and integrating traditional practices into formal education are therefore crucial for maintaining enset-based agroecosystems.

Globally, these findings reinforce the importance of documenting and integrating indigenous knowledge into agricultural and development frameworks. In regions cultivating perennial root crops like cassava, yam, and taro, community-based knowledge has proven essential for crop improvement, pest management, and climate adaptation [70, 93, 105]. For Ethiopia, strengthening indigenous knowledge systems alongside modern innovations can enhance productivity, promote sustainability, and ensure cultural continuity.

Table 2. Independent t-test Analysis of Indigenous Knowledge by Gender and Literacy

Parameters	Informant groups	*N*	*Mean ± SD*	*t -value*	*p – value*
Gender	Male	136	5.1±2.3	0.1	*P=0.89*
	Female	68	5.06±2.2		
Literacy level	Illiterate	127	5.9±2.0	5.7	*P<0.05*
	Literate	77	4.4±1.9		

Table 3. ANOVA Analysis of Indigenous Knowledge by Age Groups

Source of Variation	Df	SS	MS=SS/Df	F Ratio	*P-value*

Between Groups	2	15.155	7.578	12.94	*P=0.000*
Residual (within)	201	117.841	0.586		
Total	203	132.996	8.164		

Note: **Df**=degree of freedom, **SS**= Sum of Squares, **MS**= Mean of Square, Significant codes: 0.05

Preference Ranking of Enset Varieties

The preference ranking of enset (*Ensete ventricosum*) varieties in the study area reflects the multifunctional use of this indigenous crop and underscores the sophisticated indigenous knowledge held by farmers. The findings indicate that farmers prioritize varieties differently based on intended use kocho, bulla, amicho, fiber, or medicinal applications demonstrating an intricate understanding of varietal characteristics and their contributions to household nutrition, livelihoods, and cultural practices (Table 4).

Kocho quality was the primary determinant for variety selection, with Nobo, Bejo, and Bocho emerging as the most preferred. In contrast, bulla quality favored varieties such as Agen, Gosheno, and Tayo, while amicho selection prioritized Echiwi, Kello, and Geyo. These distinctions underscore the multifunctionality of enset and the context-specific selection criteria employed by farmers, aligning with findings in other Ethiopian regions where varietal preference is linked to the type of end product [13, 29, 33]. Fiber and medicinal properties further influenced varietal choice, with Wuo'o and Shuri highly valued, indicating that non-food uses of enset are integral to rural livelihoods. Similar multifunctional valuation of indigenous crops has been reported globally, such as yam (*Dioscorea spp.*) in West Africa and taro (*Colocasia esculenta*) in the Pacific, where farmers differentiate varieties based on culinary quality, storage potential, fiber use, and medicinal properties [59, 93].

The deliberate and nuanced selection of enset varieties illustrates the deep ecological and cultural knowledge embedded in local farming systems. Farmers' criteria for selection not only reflect nutritional and economic considerations but also encompass social and medicinal values, contributing to the resilience and sustainability of enset-based agroecosystems. Such practices are critical for maintaining intraspecific diversity, as farmers actively conserve preferred varieties while responding to environmental, market, and cultural pressures.

From a conservation and agricultural development perspective, these findings have several implications. First, prioritizing the protection and propagation of highly valued varieties can enhance food security, improve nutritional outcomes, and preserve cultural heritage. Second, understanding farmers' preference criteria provides a foundation for participatory breeding programs, which can integrate local knowledge with scientific approaches to improve yields, quality, and resilience [13, 33]. Third, recognizing the multifunctionality of enset underscores the need for holistic management strategies that support both food and non-food uses, including fiber production, traditional medicine, and ecological services such as soil stabilization and water conservation.

Globally, these results emphasize the importance of context-specific knowledge in crop management and conservation. In regions cultivating multifunctional root and tuber crops, the integration of farmers' indigenous knowledge with formal agricultural research has proven essential for sustaining crop diversity, improving livelihoods, and adapting to climate variability [93, 105, 110]. In Ethiopia, leveraging farmers' preferences for specific enset varieties can guide targeted interventions in germplasm conservation, breeding, and extension services, ultimately supporting the sustainability and resilience of enset-based farming systems.

Table 4. Preference Ranking of *Ensete ventricosum* Varieties Based on Food, Fiber, and Medicinal Value

Selection criteria	Enset local variety	Key informants													
		R1	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**	**R11**	**R12**	**Total**	**Rank**
Kocho quality	Adiyo	6	7	8	5	6	2	6	7	8	7	3	8	73	6
	Bejo	11	10	9	12	11	9	11	9	10	11	12	10	125	2
	Bocho	10	11	10	11	10	12	10	11	9	10	10	11	123	3
	Choro	4	6	4	4	3	6	4	3	4	3	2	7	50	9
	Geyo	2	2	3	2	1	8	1	2	3	2	5	5	36	10
	Gudero	9	8	7	9	8	7	9	8	7	8	11	6	97	4
	Gosheno	5	5	6	8	7	5	5	5	6	5	1	9	62	8
	Kebo	1	3	4	1	2	4	1	1	2	1	6	4	30	12
	Kopier	7	9	5	6	5	3	7	6	5	6	8	3	70	7
	Mechadame	3	4	2	3	4	1	3	4	1	4	4	2	35	11
	Nobo	12	12	11	10	12	10	12	12	11	12	9	12	135	1
	Wuo'o	8	1	1	7	9	11	8	10	12	9	7	1	84	5
Bulla quality	Agen	12	11	10	11	12	12	9	12	8	11	12	11	131	1
	Bocho	4	5	4	5	4	3	3	5	4	6	5	4	52	5
	Gosheno	11	10	11	12	10	10	12	11	9	10	9	10	125	2
	Nobo	1	2	1	1	2	1	2	1	2	2	1	1	17	6
	Tayo	10	12	12	10	9	11	11	8	10	12	8	9	123	3
	Yeko	6	4	4	3	7	4	5	3	4	4	3	6	53	4
Amicho quality	Ateri	4	5	8	6	8	4	8	4	8	4	9	7	75	4
	Echiwi	12	11	12	11	12	9	11	10	12	10	11	12	133	1
	Geyo	10	10	9	8	10	11	10	11	8	8	9	11	115	3
	Gosheno	1	3	1	2	4	3	5	5	6	3	2	1	36	5
	Kello	11	12	10	9	11	10	12	9	9	8	11	10	122	2
Fiber value	Adiyo	9	7	8	6	7	8	7	9	6	9	10	8	94	4
	Echiwi	2	4	3	4	3	2	4	5	2	3	4	4	40	5
	Epo	8	10	9	7	8	7	9	7	8	8	7	7	95	3
	Shuri	3	2	2	4	2	5	6	2	4	5	6	3	44	6
	Kebo	9	8	10	8	11	9	8	8	11	7	8	10	107	2

	Wuo'o	10	11	12	9	9	10	11	10	9	10	11	9	121	1
Medicinal value	Choro	10	9	7	7	8	8	10	7	6	5	7	7	91	4
	Mechadame	9	8	6	9	10	9	9	6	8	8	9	6	97	3
	Tayo	11	10	9	12	8	11	9	10	11	12	9	11	123	2
	Shuri	12	11	10	11	9	12	11	8	12	10	12	10	128	1

Direct Matrix Ranking of Multi-Purpose Enset Varieties

The direct matrix ranking (DMR) of enset (*Ensete ventricosum*) varieties demonstrates the multifunctional role of this crop in southern Ethiopian agroecosystems. Among the five locally important varieties evaluated, Nobo consistently emerged as the most valued across multiple use criteria food, medicinal value, fiber, fodder, and drought resistance highlighting its integral role in household nutrition, health, and livelihood security. Similarly, Gosheno and Tayo (Table 5) were recognized for their versatility, though specific uses varied, indicating that farmers strategically select varieties based on intended household applications. These findings corroborate previous Ethiopian studies, where enset varieties are ranked differently depending on food quality, fiber yield, medicinal properties, and environmental resilience [13, 18, 20, 25, 34].

The prioritization of varieties such as Nobo and Gosheno illustrates the depth of indigenous knowledge and the nuanced decision-making of local farmers. This aligns with observations in other root and tuber crop systems globally, where farmers' varietal selection integrates multiple objectives, including culinary suitability, non-food utility, and environmental adaptability. For example, yam (*Dioscorea spp.*) in West Africa and taro (*Colocasia esculenta*) in the Pacific are similarly ranked based on multifunctionality, demonstrating a convergence in how smallholder farmers value diversity for resilience and livelihood security [59, 70, 93, 105].

The DMR results further underscore the ecological and socio-economic importance of enset. Nobo's high scores in fodder and drought resistance indicate that multifunctional varieties contribute not only to household food security but also to livestock productivity and climate resilience. In Ethiopia, this is particularly relevant as enset is cultivated in regions prone to erratic rainfall and environmental stress, providing a perennial and drought-tolerant staple that buffers against food insecurity [20, 34, 43]. Globally, similar multifunctional crop systems, including cassava in Latin America and sweet potato in East Africa, illustrate how farmer knowledge guides the selection of resilient, multipurpose varieties to meet household needs under climate variability [59, 70, 93].

Table 5. Direct Matrix Ranking (DMR) of Five Multipurpose Enset Varieties

Use value	Local Enset varieties																										
	Bejo					**Bocho**					**Gosheno**					**Nobo**					**Tayo**					**Total**	**Rank**
	R1	**R2**	**R3**	**R4**	**R5**	**R1**	**R2**	**R3**	**R4**	**R5**	**R1**	**R2**	**R3**	**R4**	**R5**	**R1**	**R2**	**R3**	**R4**	**R5**	**R1**	**R2**	**R3**	**R4**	**R5**		
Food	3	4	2	2	3	5	5	4	3	5	4	5	3	4	5	1	2	3	3	1	5	4	5	5	4	76	1
Medicinal value	5	3	4	5	3	2	1	2	1	1	4	5	3	4	4	3	4	5	3	5	1	2	1	2	2	75	2
Fiber	1	2	3	2	4	2	1	2	1	2	2	1	1	1	2	4	3	2	5	3	3	4	4	2	1	72	4
Fodder	3	2	2	1	1	1	1	1	3	1	2	5	3	4	5	4	4	5	5	4	5	3	4	2	3	74	3
Drought resistant	5	1	3	1	4	2	5	2	4	5	3	3	2	1	5	4	5	1	3	2	1	2	1	2	3	70	5
Total		**69**					**62**					**81**					**84**					**70**					
Rank		**5**					**3**					**2**					**1**					**4**					

Status of Enset Cultivation in the Study Area

Enset (*Ensete ventricosum*) continues to be the cornerstone of food security and livelihood resilience in southern Ethiopia, providing multifunctional benefits as a source of food, fiber, medicine, and cultural significance [7, 8, 10]. Despite its critical role, the current study indicates a worrying decline in both the diversity and abundance of enset varieties, with over half of the respondents (53.92%) perceiving a reduction in cultivation. These observations mirror findings from Gedebano Gutazer Welene and the Gurage zone, where household-level studies similarly report declining enset acreage and varietal richness due to a combination of biotic and socio-economic factors [11, 17, 77, 111].

Biotic stresses, including bacterial wilt and damage from porcupines and mole rats, remain major constraints on enset productivity. These pressures are compounded by environmental factors, such as soil degradation and climate variability, which reduce both yield and plant vigor. Comparable challenges have been documented in other perennial staple crops worldwide, including cassava in West Africa and taro in the Pacific, where pest and disease pressures, combined with environmental stressors, threaten varietal diversity and local food security [70, 105]. Such parallels underscore the global relevance of integrating traditional knowledge with modern agronomic practices to maintain crop resilience.

Socio-cultural dynamics further exacerbate the decline in enset cultivation. Younger generations increasingly prioritize cash crops and urban migration over traditional farming, contributing to reduced intergenerational knowledge transfer and diminished interest in maintaining diverse enset varieties. Similar trends are reported in yam and sweet potato cultivation systems in other regions, where younger farmers show limited engagement with traditional staples, potentially jeopardizing the long-term conservation of local germplasm [93, 105].

Major Threats Reducing Enset Productivity in the Study Area

Enset (*Ensete ventricosum*) productivity in the study area is constrained by a complex interplay of biotic, environmental, and socio-economic factors. The most pressing threats, as reported by respondents, include bacterial wilt (Nuushoo, 45.58%), mole rats (Eccee, 21.56%), general animal attacks (15.68%), porcupines (Caayo, 9.8%), and wild pigs (7.3%) (Figure 14). Additional challenges such as leaf hoppers, agricultural expansion, declining interest among younger farmers, and limited institutional support further exacerbate productivity losses. These findings corroborate reports from Wolaita, Sheka, Gurage, and Sidama zones, where bacterial wilt and animal pests are consistently identified as major constraints to enset cultivation [7, 13, 48, 50, 63, 77].

Bacterial wilt, caused by *Xanthomonas campestris pv. musacearum*, remains the most destructive enset disease across southern Ethiopia. Farmers' indigenous management strategies such as avoiding tool sharing, regular leaf pruning, uprooting and burning infected plants, crop rotation, and planting resistant varieties play a crucial role in limiting disease spread [12, 25, 112, 113]. Complementary practices, including the application of fresh ash around affected corms and intercropping with *Pycnostachys abyssinica* (Yee'ero), reflect a nuanced understanding of plant-pathogen interactions, highlighting the value of traditional ecological knowledge in enhancing crop resilience [13, 14, 114].

Rodent and wildlife damage, particularly from mole rats and porcupines, represents another critical limitation. Farmers employ a combination of physical barriers, filling burrows, guard dogs, and scare tactics to protect enset plants. While these measures are labor-intensive and context-specific, they exemplify adaptive strategies that smallholder farmers globally use to mitigate crop losses from wildlife, comparable to maize and cassava systems in East Africa and Southeast Asia [115].

Socio-economic and land management factors compound these biological threats. Inadequate land availability, land fragmentation, and encroachment by cash crops reduce the area devoted to enset, undermining varietal diversity and long-term food security. Similar dynamics have been observed in tropical perennial staples worldwide, including taro in the Pacific and yams in West Africa, where expansion of market-oriented agriculture and reduced intergenerational knowledge transfer threaten both productivity and agrobiodiversity [70, 93].

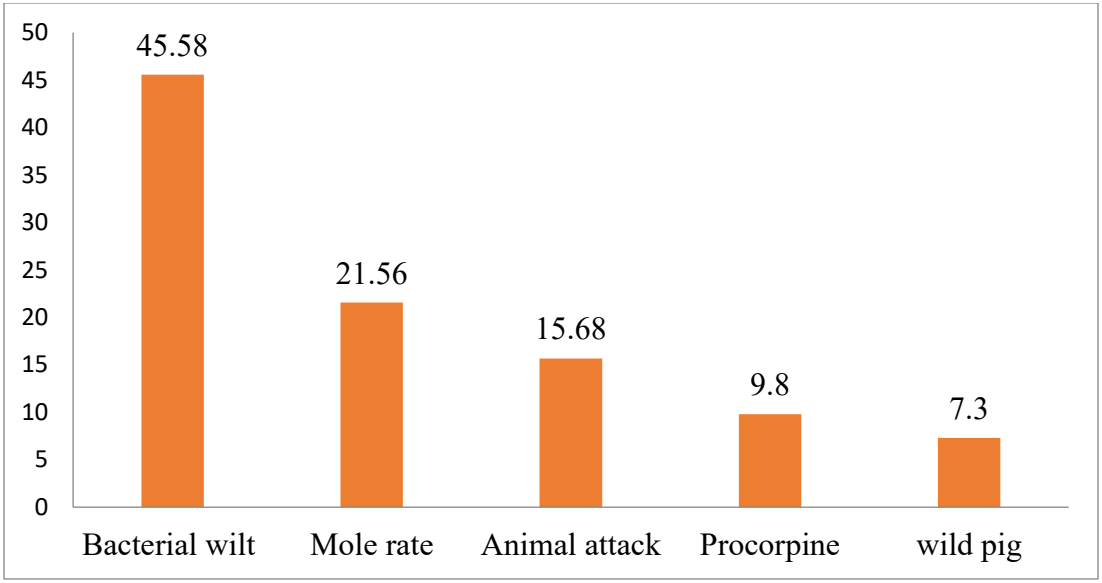

Figure 14. Proportion of threatening factors affecting enset (*Ensete ventricosum*) in the study area

Indigenous Knowledge of Enset Cultivation and Management Practices in the Study Area

The study demonstrates that indigenous knowledge plays a central role in enset (*Ensete ventricosum*) propagation and cultivation, sustaining both productivity and cultural heritage in the study area (Figure 15). Farmers predominantly employ vegetative propagation through suckers derived from mature plants, consistent with previous studies in southern Ethiopia [7, 13, 18, 34]. This method ensures genetic fidelity, facilitates rapid multiplication, and supports the maintenance of locally adapted landraces. The careful selection of healthy suckers based on growth potential, morphology, and vigor exemplifies farmers' nuanced understanding of plant physiology, highlighting the sophistication of traditional agronomic knowledge.

Vegetative propagation practices observed in the study are comparable to those documented for other perennial staple crops globally. For example, vegetative propagation is similarly critical for crops such as cassava (*Manihot esculenta*) in West Africa and taro (*Colocasia esculenta*) in the Pacific, where farmers rely on clonal reproduction to maintain preferred traits, ensure uniformity, and sustain cultural food practices [59, 105]. This parallel underscores the universal importance of farmer-led propagation strategies in conserving agrobiodiversity while enhancing food security.

Land preparation and crop management practices in the study area further demonstrate the integration of indigenous knowledge with sustainable agricultural principles. Farmers employ optimal plant spacing, mulching, organic fertilization, and the timely removal of diseased or pest-infested plants to optimize enset growth. The preference for organic compost and residual straw reflects both resource availability and recognition of the benefits for soil fertility, echoing findings in Wolaita and Gurage zones where organic inputs have been shown to improve yields and maintain soil health [9, 17]. Such practices align with sustainable intensification frameworks, demonstrating that traditional methods can complement modern agronomic techniques to enhance resilience against environmental and biotic stresses.

The propagation system involving corm trimming and removal of the central bud to stimulate offshoot development is a notable example of indigenous innovation. This technique, which can yield between 15 and 150 offshoots per corm, illustrates how local farmers have optimized reproductive efficiency to ensure a stable supply of planting material. Similar knowledge-driven approaches are reported for other perennial staples, including yams in West Africa and bananas in East Africa, where targeted manipulation of mother plants improves vegetative propagation rates and sustains household food security [59, 72, 84, 105].

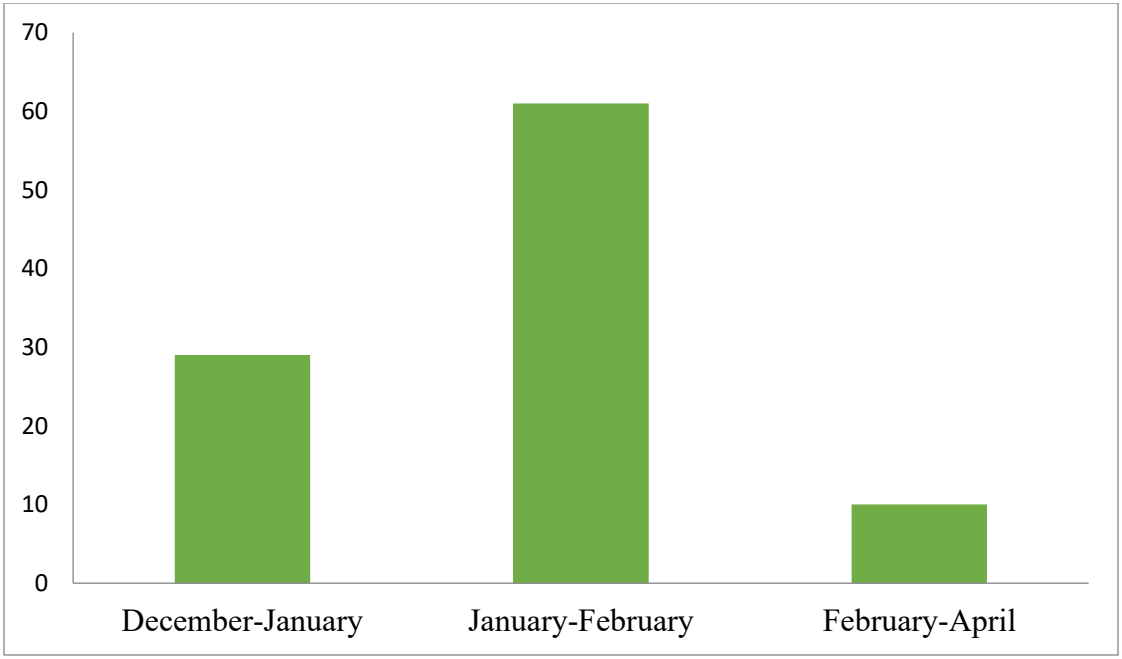

Figure 15. Months of enset (*Ensete ventricosum*) propagation in the study area

Conclusion

Enset (*Ensete ventricosum*) remains a cornerstone of food security, rural livelihoods, and cultural identity in the Bita District of the Kaffa Zone, Southwestern Ethiopia. This study demonstrates that indigenous knowledge plays a central role in enset cultivation, encompassing propagation, pest and disease management, fertilization, and post-harvest processing. Farmers' expertise in selecting healthy suckers, applying organic fertilizers, implementing traditional pest control, and processing enset products ensures sustainable production while preserving cultural values. Preference and matrix ranking analyses revealed that local communities prioritize specific landraces such as *Nobo* and *Gosheno* for their multifunctionality, including food quality, fiber production, medicinal applications, fodder, and drought resilience. This highlights the sophistication of local varietal selection, reflecting a deliberate strategy to maximize nutritional, economic, and ecological benefits.

Despite its importance, enset cultivation is increasingly threatened by bacterial wilt, mole rat infestations, porcupines, wild pigs, leaf hoppers, land scarcity, and declining youth engagement. These challenges, compounded by limited governmental support, are driving reductions in the diversity and abundance of enset landraces. Statistical analyses further indicate that age, rather than gender or formal education, strongly influences indigenous knowledge, underscoring the urgent need for intergenerational transfer to sustain traditional farming systems.

The findings highlight the necessity of integrating indigenous knowledge with modern agricultural innovations to enhance productivity, resilience, and biodiversity conservation. Policies should prioritize the development and dissemination of disease-resistant landraces, improved land management practices, and youth-oriented capacity-

building programs. By valorizing farmers' traditional expertise and recognizing enset's socio-cultural and ecological significance, stakeholders can strengthen local food systems, safeguard biodiversity, and enhance the long-term resilience of enset-based agriculture in Ethiopia.

Limitations of the Study

This study, while comprehensive in documenting indigenous knowledge and enset cultivation practices in Bita District, was limited to selected kebeles, restricting generalizability to other regions. Data relied on interviews, focus groups, and surveys, which may introduce reporting biases. Seasonal variations, quantitative yield measurements, and nutritional analyses were not captured, limiting evidence on productivity and effectiveness of practices. Modern technological interventions and youth perspectives were underrepresented. Threat assessments were based on perceptions rather than systematic measurements. Time, resources, and sample size constraints further restricted field and laboratory validation, highlighting the need for broader, multi-seasonal, and multi-regional studies.

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Authors' contributions

AA contributed to the original draft, data collection, and methodology. KC participated in writing, reviewing, carried out the official identification of the plant material and editing. GG was involved in writing, reviewing, and data collection, as well as formal analysis. AA participated in writing, reviewing, carried out the official identification of the plant material and editing.

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Data availability

All data supporting the findings of this study are available within the manuscript.

Declarations

Ethics approval and consent to participate

All necessary permissions for field sampling were obtained prior to data collection. Sampling in the study area was carried out with prior informed consent from relevant landowners and/or local community leaders, and with formal authorization from the Bita District Administrative and Agricultural Offices. Collections took place on both private and public lands, in full compliance with Ethiopian regulations governing plant specimen collection.

Consent for publication

Not applicable: this manuscript has no personal data from the authors

Competing interests

The authors declare no competing interests.

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