



The Forgotten Frontiers of Agriculture: Domestication and the Multifaceted Value of Underutilized Indigenous Crops: A Review

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ABSTRACT

Neglected and underutilized indigenous crops represent a critical but overlooked resource for mitigating global food insecurity, climate change and the loss of biodiversity. These species exhibit remarkable adaptability, high nutritional value and significant cultural importance; however, they remain marginalized owing to insufficient research, inadequate market integration, a lack of supportive policies and the erosion of traditional knowledge systems crucial for sustainable agriculture. This study presents a systematic review adhering to the PRISMA framework, which employs a hybrid of bibliometric and qualitative synthesis. We analysed scholarly and institutional publications spanning 2010-2025 with NVivo 14, concentrating on the policy, ecological and socio-economic dimensions related to the improvement, domestication and use of underutilized native crops in Sub-Saharan and other developing regions. Evidence indicates that the domestication and incorporation of underutilized crops provide substantial co-benefits for biodiversity conservation, climate resilience, food security and rural livelihoods. From an ecological perspective, these species augment agrobiodiversity, improve soil health and enhance adaptation to drought and heat. Nutritionally, they supply diverse micronutrients and proteins that are lacking in major staple crops, thus improving dietary quality. On a socio-cultural level, they preserve indigenous knowledge, foster food sovereignty and empower local populations. Economically, they create diverse income streams and bolster rural value chains when facilitated by equitable market systems. However, progress is hindered by ongoing challenges, including insufficient research funding, disorganized seed systems, underdeveloped value addition and policy neglect. This review posits that realizing the potential of these crops requires integrating genomics, participatory breeding and community-led value chains within supportive policy frameworks. Sustainable domestication efforts must reconcile productivity objectives with the preservation of genetic, ecological and cultural integrity.

Key words: Climate resilience, Crop diversity, Domestication, Food security, Indigenous crops nutritional security, Participatory breeding, Traditional knowledge, Underutilized species.

The global food system faces mounting vulnerabilities from climate change, pests and malnutrition, largely due to a historical reliance on a narrow range of staple crops that has reduced agricultural biodiversity and resilience (Molotoks *et al.*, 2020; Abberton *et al.*, 2015). As climate change increases the vulnerability of agriculture worldwide, food security is urgently needed due to rising weather variability, depletion of resources and ecological disturbances (Manjeet *et al.*, 2023). Indigenous crops, which are adapted to local environments and cultures, offer a strategic pathway to diversify food production and enhance sustainability (Mayes *et al.*, 2012). Many underutilized species are well adapted to marginal lands and with low cost inputs and may thus be of great benefit for the survival of poor communities, employment generation and sustainability of agricultural ecosystems (Barua *et al.*, 2019). However, they remain underutilized due to socio-economic barriers such as inadequate policy, weak markets and limited research (Akinola *et al.*, 2020; Thakur, 2014). Their continued exclusion from formal agricultural systems accelerates genetic erosion and marginalization (Lichun *et al.*, 2018). For example, in Ethiopia, there is a growing concern about the loss of genetic diversity for 'minor' root and tuber crops, which reduces its contribution to food security of the people (Zerihun, 2022).

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Many indigenous species exist in an intermediate state between wild and fully domesticated forms, often maintained through farmer-led selection, a process that

preserves valuable genetic diversity and local adaptation (Goron and Raizada, 2015; Razifard *et al.*, 2020). These fruit crops have not undergone any conscious phase of domestication and selection and their cultivation is very restricted, yet they can thrive even under most adverse situations (Barua *et al.*, 2019). Effectively integrating these crops into contemporary agriculture therefore requires a dual focus: understanding their domestication pathways and addressing the socio-structural constraints that limit their scaling.

This review argues that advancing the cultivation of indigenous crops is critical for building resilient food systems in the face of climate change and population growth (Mabhaudhi *et al.*, 2022). Climate resilient agriculture (CRA) addresses these issues by focusing on conserving and optimizing soil resources and promoting biodiversity (Kujur *et al.*, 2026). To that end, it synthesizes current knowledge on the benefits, domestication processes and key barriers, from genetic improvement and participatory breeding to market access and policy reform, that shape their potential. By bridging the gap between domestication science and socio-economic analysis, this paper provides a cohesive framework for leveraging neglected and underutilized species (NUS) as catalysts for food security, agroecological resilience and sustainable livelihoods.

Theoretical framework and research approach

Theoretical framework

This review employs a holistic systems perspective, framing the process of domesticating underutilized indigenous crops as a confluence of biodiversity preservation, enhanced climate resilience, strengthened food and nutritional security and the perpetuation of cultural heritage. Informed by agroecological principles and resilience theory, domestication is conceptualized as a dynamic continuum. This continuum spans from wild progenitors through semi-domesticated varieties to cultivated modern breeds, driven by human selection and the intertwined co-evolution of culture and crops. This is supported by the work of Meyer and Purugganan (2013).

This framework is structured around four interconnected dimensions:

- i. Ecological and genetic dimension:** This dimension focuses on adaptation, the maintenance of genetic diversity and the capacity for environmental resilience. It underscores the critical role of conserving genetic resources as both a foundational element and a direct outcome of sustainable domestication efforts (Dempewolf *et al.*, 2017; Bohra *et al.*, 2022).
- ii. Socio-cultural dimension:** This aspect acknowledges domestication as a form of social innovation, intricately shaped by traditional knowledge systems, cultural values and localized food economies (Modest *et al.*, 2021).
- iii. Economic and market dimension:** Here, the focus is on the development of value chains, market accessibility

and the diversification of livelihoods as key catalysts for adoption and the fair distribution of benefits (Mgwenya *et al.*, 2025).

- iv. Governance and policy dimension:** This dimension highlights the significance of institutional structures and policy interventions that influence research priorities, conservation strategies and equitable benefit-sharing mechanisms.

Sustainable domestication is considered achieved when these dimensions interact synergistically to preserve ecological integrity, safeguard genetic diversity and uphold cultural authenticity, while simultaneously improving food security and fostering socio-economic inclusion. The conceptual model thus connects foundational inputs, such as knowledge, research and policy, with the dynamic processes of domestication, participatory breeding and market development, ultimately leading to desirable outcomes like biodiversity stewardship, community empowerment and the establishment of climate-resilient systems.

Research methodology

A systematic review was undertaken, adhering rigorously to the PRISMA 2020 guideline. This approach combined bibliometric analysis with a qualitative synthesis to systematically examine the existing literature pertinent to the domestication and utilization of underutilized indigenous crops.

Literature search strategy

Peer-reviewed academic publications spanning the period from 2010 to 2025 were systematically retrieved from prominent databases including Scopus, Web of Science, ScienceDirect, PubMed and Google Scholar. The initial search identified 2,543 records. Searches were executed using Boolean operators to combine keywords such as:

("indigenous crops" OR "underutilised crops" OR "orphan crops") AND ("domestication" OR "crop improvement") AND ("food security" OR "climate resilience" OR "biodiversity conservation").

In addition to academic articles, relevant grey literature and institutional reports from organizations such as the FAO, CGIAR and IPBES were also incorporated into the review.

Criteria for study inclusion and exclusion

Studies were included if they met the following criteria:

- Centrally focused on the domestication, enhancement, or application of underutilized crops.
 - Reported findings related to ecological, socio-economic, or policy impacts.
 - Were published in English and had undergone peer review.
- Studies were excluded if they:
- Primarily addressed major staple crops without a specific focus on underutilized varieties.
 - Lacked sufficient methodological rigor in their design or reporting.

Following the removal of duplicates and a two-stage screening process (title/abstract, then full-text), 38 studies were included for the final qualitative synthesis.

Data extraction and analysis procedures

Data extracted from the selected studies were systematically coded using NVivo 14 software and subsequently organized into five primary analytical themes:

- Ecological and genetic diversity considerations.
- Domestication and crop breeding processes.
- Socio-cultural knowledge and practices.
- Market dynamics and economic systems.
- Governance structures and policy frameworks.

Thematic and narrative analysis techniques were then employed to synthesize patterns, identify emergent trends, address contradictions and pinpoint existing research gaps.

Synthesis of findings

A narrative synthesis approach was adopted to integrate the qualitative and quantitative findings derived from the reviewed literature. This process involved three distinct analytical stages:

- Mapping the existing body of evidence.
- Categorizing the benefits and challenges associated with domestication thematically.
- Synthesizing the findings within the established conceptual framework to discern and articulate sustainability outcomes.

Ethical considerations

This review did not involve the collection of primary data. Ethical principles were rigorously maintained through accurate attribution of sources and due recognition of indigenous knowledge. The study also operates in alignment with the principles of the Nagoya Protocol on Access and Benefit Sharing (ABS).

Anticipated contributions

This review is expected to yield the following significant contributions:

- The development of a comprehensive conceptual model that elucidates the interconnections between crop domestication processes and both ecological and socio-economic sustainability.
- The identification of critical research lacunae in areas such as genomics, participatory breeding approaches and market development strategies for underutilized crops.
- The provision of a policy-focused roadmap designed to guide the integration of underutilized crops into broader climate-smart agricultural initiatives.

Defining indigenous and underutilized crops in context

A variety of terms, such as underutilized species, *orphan crops*, *underutilized species*, *minor crops*, *traditional crops* and *neglected species*, are used to describe plant species that are not widely cultivated in mainstream agriculture. For the purposes of this discussion, “indigenous crops”

refers to plant species that either originated in a specific region or have undergone significant diversification there and are strongly linked to the food systems, ecological knowledge and cultural traditions of local and indigenous communities (Hunter *et al.*, 2019). Passed down through informal seed systems and generations of farmer selection, these crops have developed unique adaptations to suit local environmental conditions and socio-cultural needs (Mabhaudhi *et al.*, 2019a).

The label ‘underutilized’ indicates that these species, despite their potential benefits for food and nutritional security, agrobiodiversity conservation and climate change resilience, receive limited attention in global agricultural research, policy and commercial development (Tadele, 2019). Their potential remains largely unrealized due to historical neglect, limited genetic enhancement, weak value chains and insufficient institutional support (Woldeyohannes *et al.*, 2022).

While globally dominant crops like wheat, maize and rice are bred extensively for high-input agricultural systems, indigenous crops are often chosen for characteristics suited to traditional farming practices, such as drought resistance, pest immunity, minimal input needs and cultural or medicinal value. These crops, geographically and ecologically varied, include African leafy vegetables (*Amaranthus* spp., *Corchorus* spp., *Solanum nigrum*), climate-resilient grains like fonio (*Digitaria exilis*) and finger millet (*Eleusine coracana*), tuber crops like indigenous yams (*Dioscorea* spp.) andean root vegetables (*oca*, *ulluco*) and pseudo-cereals like quinoa and amaranth (*Chenopodium quinoa*, *Amaranthus* spp.) (Termote *et al.*, 2021). Frequently, they function as biocultural keystone species, representing the combined ecological and cultural heritage of indigenous communities (Mattalia *et al.*, 2024).

Domestication, from a biological and evolutionary perspective, is a continuous and evolving process of human-driven selection that leads to heritable genetic changes, distinguishing cultivated plants from their wild relatives. Typical domestication traits encompass loss of seed dormancy, larger seed or fruit size, uniform ripening and reduced natural dispersal or toxicity (Meyer and Purugganan, 2013). Many indigenous crops are still in this phase of domestication, an ongoing and non-linear process influenced by localized selection pressures and preferences. These prioritize versatility, adaptation to challenging environments and cultural significance over the limited productivity measures emphasized in industrial agriculture (Modest *et al.*, 2021). This creates a diverse range of semi-domesticated species that connect wild and cultivated ecosystems, especially within smallholder and traditional agroecological systems.

Significance of indigenous crops: A multifaceted perspective

Indigenous crops hold significance far beyond their direct role in local food production, serving vital ecological,

nutritional, cultural and economic purposes. Experts increasingly acknowledge their essential contribution to sustainable agriculture, especially given current challenges like climate change, biodiversity loss and the vulnerability of global food systems (IPBES, 2019). Table 1 below synthesizes these core advantages.

Biodiversity and genetic resources

The cultivation and preservation of indigenous, often underutilized, crops are crucial for boosting agrobiodiversity, which in turn strengthens ecosystem resilience and genetic variety within our food supply (Hunter *et al.*, 2019). Unlike single-crop monocultures, these diverse species possess a wealth of valuable traits for enduring environmental stresses such as drought, heat, salinity and pests—characteristics essential for crops to adapt to a changing climate (Dempewolf *et al.*, 2017; Jamnadass *et al.*, 2020). Their genetic material is not only vital for improving the indigenous crops themselves but also provides specific genes (alleles) that can enhance major staple crops through techniques like pre-breeding and introgression (Tadele, 2019). Losing these genetic resources, often due to widespread adoption of major crops and insufficient institutional backing, means a permanent loss of future adaptability (Modest *et al.*, 2021).

Ecological sustainability

Many indigenous crops flourish in challenging, marginal environments where traditional cash crops struggle. They are foundational to traditional agroecological

practices, requiring minimal inputs and conserving resources effectively (Chivenge *et al.*, 2015; Altieri and Nicholls, 2017). Growing these crops offers significant ecological benefits, including restoring soil fertility, preventing erosion and improving water retention. When grown alongside other crops in polyculture systems, they boost overall biodiversity, attract beneficial insects and microbes and lessen the need for artificial fertilizers and pesticides (Mabhaudhi *et al.*, 2019).

Nutritional security and health

Often overlooked, indigenous crops frequently boast better nutritional content than many globally consumed staples. For instance, numerous leafy vegetables are packed with vital micronutrients like iron, zinc, calcium and vitamins A and C, while pseudocereals such as quinoa and amaranth provide complete proteins and essential fatty acids (Smith and Maunder, 2022). Incorporating these crops into local diets can effectively address ‘hidden hunger,’ reduce widespread micronutrient deficiencies and help prevent non-communicable diseases linked to poor dietary balance (John and Vicent, 2025). Expanding food diversity with these crops aligns perfectly with the concept of nutrition-sensitive agriculture, which aims to ensure both sufficient calories and high-quality diets (Li and Siddique, 2020).

Socio-cultural heritage and traditional knowledge

Indigenous crops are intrinsically linked to cultural identity, traditional rituals, and vast systems of ethnobotanical knowledge (Saensouk *et al.*, 2025). They represent

Table 1: Multifaceted benefits of utilizing indigenous crops.

Benefit	Key contributions	Illustrative examples and evidence
Ecological and genetic	Enhances agrobiodiversity and ecosystem resilience; Provides genetic resources for climate adaptation (drought, heat, pest resistance). Serves as a foundation for low-input, regenerative agroecological practices (Chivenge <i>et al.</i> , 2015; Dempewolf <i>et al.</i> , 2017).	Fonio (<i>Digitaria exilis</i>), drought-tolerant millets and indigenous yams (<i>Dioscorea</i> spp.) embody stress-adapted traits. Their use in polycultures supports soil health and biodiversity (Mabhaudhi <i>et al.</i> , 2019).
Nutritional and health	Addresses micronutrient deficiencies (“hidden hunger”) through superior profiles of vitamins, minerals, proteins and fiber. Promotes dietary diversity and nutrition-sensitive agriculture (Fanzo <i>et al.</i> , 2020; Smith and Maunder, 2022).	African leafy vegetables (<i>Amaranthus</i> , <i>Corchorus</i>) are rich in iron and calcium. Pseudocereals like quinoa and amaranth provide complete protein (Mayes <i>et al.</i> , 2023).
Socio-cultural	Embodies cultural identity, traditional knowledge and rituals. Their revitalization supports intergenerational knowledge transfer, cultural empowerment and community-led governance (Sperling <i>et al.</i> , 2020).	Crops function as biocultural keystone species, with cultivation practices, seed saving and culinary uses representing deep ethnobotanical heritage (Mattalia <i>et al.</i> , 2024).
Economic and livelihood	Offers income opportunities in marginal areas via low-input requirements and niche markets. Strengthening value chains can enhance rural livelihoods and empower smallholders, particularly women (Mgwenya <i>et al.</i> , 2025).	Commercialization of baobab (<i>Adansonia digitata</i>) and fonio has created sustainable income streams in parts of Africa (Jamnadass <i>et al.</i> , 2020; Tadele, 2019).

centuries of accumulated local wisdom concerning cultivation, food processing, seed preservation, and culinary traditions. Reintroducing and nurturing these species can foster cultural empowerment and facilitate the transfer of knowledge across generations, particularly when integrated into collaborative plant breeding programs and community-managed seed networks (Modest *et al.*, 2021). Nevertheless, obstacles like cultural resistance or inadequate institutional backing can impede their wider adoption; therefore, successful projects must be culturally sensitive and driven by the communities themselves (Sperling *et al.*, 2020).

Economic potential and livelihoods

Indigenous crops offer significant economic prospects, especially for smallholder farmers in difficult growing regions. Their minimal input requirements, attractiveness to niche markets, and inherent climate resilience can lead to reliable income streams, particularly if their value chains are enhanced through processing, branding and certification (Mgwenya *et al.*, 2025). For instance, the commercial development of crops like fonio (*Digitaria exilis*) and baobab (*Adansonia digitata*) has demonstrably improved rural livelihoods across parts of Africa (Jamnadass *et al.*, 2020; Tadele, 2019). However, realizing these advantages is often hampered by hurdles like inadequate infrastructure, insufficient consumer knowledge and disorganized markets (John and Vicent, 2025; Mmbando, 2025). Successful economic transitions will likely necessitate public investment in research and agricultural extension services, coupled with institutional frameworks that ensure fair distribution of value (Mmbando, 2025; Ohlin *et al.*, 2024).

Benefits deriving from utilising indigenous crops

Harnessing the potential of native crops through proactive promotion and integration offers a multitude of interconnected advantages, ranging from enhanced food security and improved nutrition to environmental sustainability, biodiversity preservation and the empowerment of local communities. The significance of these benefits is increasingly acknowledged in global discussions about transforming food systems, achieving sustainable development and building resilience to climate change.

Bolstering food security and climate resilience

Indigenous crops are vital for climate-smart agriculture due to their inherent adaptation to local environments, including resistance to drought, heat, salinity and poor soils. Their resilience is crucial for ensuring food security amidst increasing climate variability, particularly in vulnerable regions reliant on rainfed agriculture. Incorporating indigenous species diversifies cropping systems, reducing reliance on a limited number of crops and increasing system stability and yield reliability, especially in challenging environments.

Enhancing nutrition and public health

Many native crops boast superior nutritional profiles, offering essential vitamins, minerals, proteins and fiber often lacking in staple foods. Leafy greens like Amaranthus and Corchorus are rich in iron and calcium, while pseudocereals such as quinoa and amaranth provide complete proteins. Integrating these crops into local diets is a cost-effective approach to combatting micronutrient deficiencies, particularly among women and children. Public health initiatives that promote their consumption can contribute to long-term health and prevent non-communicable diseases.

Promoting sustainable and regenerative agriculture

Indigenous crops are often grown in eco-friendly systems that require minimal chemical inputs and conserve soil and water. Utilizing them in polycultures and crop rotations enhances resilience, soil fertility and natural pest control. By supporting ecosystem services like pollination, nutrient cycling and carbon sequestration, they align with the goals of regenerative agriculture and climate change mitigation.

Facilitating dynamic on-farm conservation

Cultivating indigenous crops actively contributes to the in-situ conservation of plant genetic resources, allowing for continued evolution under farmer management. This on-farm approach not only preserves genetic diversity but also safeguards associated cultural and ecological knowledge. While gene banks play a vital role in *ex-situ* conservation, maintaining these species within their native environments ensures adaptation to evolving climate and disease pressures.

Empowering local and indigenous communities

Revitalizing indigenous crops empowers communities by leveraging their cultural and economic significance. These crops are often deeply connected to local identities, traditions and knowledge, providing a valuable resource base. Promoting them can restore pride in traditional practices, facilitate knowledge transfer between generations and create inclusive value chains that prioritize smallholder participation and equitable benefit-sharing. Market development for indigenous crops is already improving livelihoods and empowering women in various regions.

The process, challenges and implications of domestication and improvement

Realizing the potential of indigenous crops often requires strategic domestication and genetic improvement to address traits that limit cultivation or consumption, such as seed shattering, anti-nutritional compounds, or laborious processing (Bohra *et al.*, 2022). Modern approaches like marker-assisted selection and participatory plant breeding (PPB) are effective, with PPB ensuring traits align with local preferences and environments (Aziz and Masmoudi, 2025; Lebot and Viquez-Zamora, 2025).

However, systemic barriers hinder progress. The following consolidated challenges are critical:

- **Limited R and D and genetic erosion:** Chronic underinvestment in research leaves agronomic, genomic, and nutritional profiles poorly understood (Mphande, 2025). Paradoxically, domestication itself risks genetic homogenization, eroding the diversity that underpins resilience (Dempewolf *et al.*, 2017).
- **Weak seed systems and value chains:** Formal seed systems often neglect indigenous varieties, while informal networks may lack scale. Coupled with underdeveloped processing infrastructure and market access, this stifles commercial viability (John and Vicent, 2025).
- **Policy neglect and knowledge loss:** Agricultural policies frequently favor major staples, creating disincentives. Simultaneously, the intergenerational erosion of traditional knowledge threatens the conservation of cultivation and utilization practices. (Melash *et al.*, 2023; Ngonzi and Lubenga, 2020).
- **Equity and access concerns:** Commercialization raises issues of fair benefit-sharing and biopiracy, necessitating robust Access and Benefit Sharing (ABS) frameworks per the Nagoya Protocol to protect community rights (Bob and Christine, 2025; Elbert *et al.*, 2023).

Implications

Responsible domestication must be guided by a socio-technical framework that integrates formal science with farmer-led innovation and traditional knowledge. The goal is not merely yield improvement but advancing food sovereignty, cultural integrity and ecological stewardship, ensuring that crop development strengthens rather than undermines the foundational benefits these species provide (Kahane *et al.*, 2021; Massawe *et al.*, 2020).

Discussion: Navigating the path from recognition to integration

This review affirms that indigenous underutilized crops are vital resources for building sustainable and resilient food systems. However, their journey from marginalization to mainstream integration is fraught with systemic contradictions. The central challenge lies in navigating a path that enhances productivity and market viability without eroding the very genetic diversity, ecological adaptability and cultural embeddedness that constitute their core value. This discussion synthesizes the findings to highlight key tensions and propose a reframed approach for future action.

The core tension: Standardization vs. biocultural integrity

The findings reveal a fundamental tension. On one hand, domestication and improvement efforts often aim to standardize traits for wider adaptability and market appeal, a process aligned with conventional agricultural development.

On the other hand, the unique value of these crops is inherently tied to their local specificity, maintained through decentralized seed systems and traditional knowledge (Melash *et al.*, 2023). This creates a critical dilemma: how to improve yields or processing efficiency without triggering genetic homogenization or disempowering the communities who are their custodians.

The erosion of traditional knowledge is not merely a collateral loss but a direct threat to the sustainability of improvement programs themselves. As Lemchi *et al.* (2016) underscore, this knowledge is the operating manual for cultivating diverse landraces in variable environments. Therefore, future strategies must view knowledge co-creation and intergenerational transfer not as a separate challenge, but as the foundational pillar of any domestication initiative.

Reframing the framework: From linear improvement to socio-ecological innovation

The persistent challenges of underinvestment, weak seed systems and market neglect (Tadele, 2019) are symptoms of a broader systemic failure to value biocultural diversity. Addressing them requires moving beyond a linear pipeline model of “crop improvement” toward a socio-ecological innovation framework. This entails:

1. **Redefining ‘Improvement’:** Success metrics must be expanded beyond yield to include nutritional density, ecosystem service provision, climate resilience and cultural relevance. Participatory Plant Breeding (PPB) is a critical methodology here, as it embeds farmer priorities and ecological context directly into the breeding agenda (Colley *et al.*, 2022).
2. **Reconceptualizing seed systems:** Formal and informal seed systems should not be seen as mutually exclusive but as complementary. Policy support is needed to legitimize, strengthen and link community seed banks and farmer networks with national gene banks and regulatory frameworks, creating a resilient, polycentric seed governance model.
3. **Integrating ethical governance from the outset:** The issues of Access and Benefit-Sharing (ABS) cannot be an afterthought. As Elbert *et al.* (2023) argue, proactive engagement with the Nagoya Protocol and the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) is essential to design value chains that ensure equitable returns and recognize traditional knowledge as intellectual innovation.

Strategic alignment for systemic impact

To translate this reframed approach into action, targeted efforts must be strategically aligned with broader sustainable development objectives. Table 2 synthesizes key challenges and proposed future directions, explicitly linking them to relevant Sustainable Development Goals (SDGs). This alignment provides a concrete framework for

Table 2: Mapping challenges and solutions to relevant SDGs.

Challenge	Proposed solutions	Relevant SDGs
Underinvestment in R and D	Increased funding for breeding, agronomy and nutrition studies.	SDG 2 (Zero Hunger), SDG 9 (Industry, Innovation)
Weak seed systems	Support for farmer-led and formal seed system integration.	SDG 2, SDG 12 (Responsible Consumption and Production)
Processing difficulties	Develop culturally appropriate and nutrient-preserving processing technologies.	SDG 3 (Good health), SDG 8 (Decent work and economic growth)
Market constraints and value chain gaps	Build equitable, inclusive value chains; Support local food systems.	SDG 1 (No Poverty), SDG 10 (Reduced inequalities)
Loss of traditional knowledge	Document, protect and integrate indigenous knowledge in domestication efforts.	SDG 11 (Sustainable communities), SDG 16 (Peace, justice, institutions)
Genetic erosion due to standardisation	Promote participatory and decentralised breeding methods.	SDG 15 (Life on land), SDG 13 (Climate action)
Policy neglect	Mainstream indigenous crops into agricultural policy, nutrition guidelines and extension.	SDG 2, SDG 17 (Partnerships for the goals)

policymakers, researchers and funders to prioritize interventions that deliver compounded benefits across food security, environmental sustainability and social equity.

CONCLUSION

Indigenous and underutilized crops are vital for future food systems, offering genetic diversity, climate resilience, nutritional value, and cultural significance. Developing them through inclusive, participatory strategies can enhance agronomic performance and marketability without sacrificing diversity, cultural identity, or indigenous rights. This requires decentralized, farmer-led innovation, local knowledge, strategic investments in research and seed systems, supportive policies, and equitable benefit-sharing. Integrating these crops into national and global agendas will foster resilient, equitable, and culturally sensitive agri-food systems.

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Informed consent

This is a review article based on published literature and does not involve any human or animal participants, therefore informed consent is not applicable.

Conflict of interest

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REFERENCES

- Abberton, M., Batley, J., Bentley, A., Bryant, J., Cai, H., Cockram, J., Oliveira, A.C. de, Cseke, L. *et al.* (2015). Global agricultural intensification during climate change: A role for genomics *Plant Biotechnology Journal*. **14**(4): 1095-1098. <https://onlinelibrary.wiley.com/doi/10.1111/pbi.12467>.
- Akinola, R., Pereira, L.M., Mabhaudhi, T., De Bruin, S. and Rusch, L. (2020). A review of indigenous food crops in Africa and the implications for more sustainable and healthy food systems. *Sustainability*. **12**(9): 3493. <https://doi.org/10.3390/su12093493>.
- Altieri, M.A. and Nicholls, C.I. (2017). The adaptation and mitigation potential of traditional agriculture in a changing climate. *Climatic Change*. **140**(1): 33-45.
- Aziz, M.A. and Masmoudi, K. (2025). Molecular breakthroughs in modern plant breeding techniques. *Horticultural Plant Journal*. **11**(1): 15-41. <https://doi.org/10.1016/j.hpj.2024.01.004>.
- Barua, U., Das, R.P., Baruah, S.R. and Gogoi, B. (2019). Underutilized fruits of Assam for livelihood and nutritional security. *Agricultural Reviews*. **40**(3): 175-184. doi: 18805/ag.R-1936.
- Bob, F. and Christine, P. (2025). Good intentions, misaligned incentives? navigating nagoya. *American Entomologist*. **71**(4): 26-27. <https://doi.org/10.1093/ae/tmaf064>.
- Bohra, A., Kilian, B., Sivasankar, S., Caccamo, M., Mba, C., McCouch, S.R. and Varshney, R.K. (2022). Reap the crop wild relatives for breeding future crops. *Trends in Biotechnology*. **40**(4): 412-431. <https://doi.org/10.1016/j.tibtech.2021.08.009>.
- Chivenge, P., Mabhaudhi, T., Modi, A.T. and Mafongoya, P. (2015). The potential role of neglected and underutilised crop species as future crops under water scarce conditions in sub-Saharan Africa. *International Journal of Environmental Research and Public Health*. **12**(6): 5685-5711.

- Colley, M.R., Tracy, W.F., Lammerts van Bueren, E.T., Diffley, M. and Almekinders, C.J.M. (2022). How the seed of participatory plant breeding found its way in the world through Adaptive Management. *Sustainability*. **14**(4): 2132. <https://doi.org/10.3390/su14042132>.
- Dempewolf, H., Baute, G. anderson, J., Kilian, B., Smith, C. and Guarino, L. (2017). Past and future use of wild relatives in crop breeding. *Crop Science*. **57**(3): 1070-1082.
- Elbert, A.W., Engels, J.M.M., Schafleitner, R., Hintum, T.V. and Mwila, G. (2023). Critical review of the increasing complexity of access and benefit-sharing policies of genetic resources for genebank curators and plant breeders-A public and private sector perspective. *Plants (Basel, Switzerland)*. **12**(16): 2992. <https://doi.org/10.3390/plants12162992>.
- Goron, T. and Raizada, M. (2015). Genetic diversity and genomic resources available for the small millet crops to accelerate a new green revolution. *Frontiers in Plant Science*. **24**(6): 157. <https://www.frontiersin.org/articles/10.3389/fpls.2015.00157/full>.
- Hunter, D., Borelli, T., Beltrame, D.M. and Oliveira, C. (2019). The potential of neglected and underutilized species for improving diets and nutrition. *Planta*. **250**(3): 709-729. <https://link.springer.com/article/10.1007/s00425-019-03169-4>.
- IPBES (2019). Global Assessment Report on Biodiversity and Ecosystem Services. Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.
- Jamnadas, R., Dawson, I.K., Parkouda, C. et al. (2020). Enhancing African orphan crops with genomics. *Nature Genetics*. **52**(4): 356-360.
- Jan, N., Hussain, S.Z., Naseer, B. and Bhat, T.A. (2023). Amaranth and quinoa as potential nutraceuticals: A review of anti-nutritional factors, health benefits and their applications in food, medicinal and cosmetic sectors. *Food Chemistry: X*. **18**: 100687. <https://doi.org/10.1016/j.fochx.2023.100687>.
- John, I. and Vicent, V. (2025). A deep dive into the dynamics of indigenous crops: nutritional value, production patterns, and market accessibility in Southern Highlands of Tanzania. *Front. Sustain. Food Syst.* **9**: 1570750. <https://doi.org/10.3389/fsufs.2025.1570750>.
- Kahane, R., Hodgkin, T., Jaenicke, H. et al. (2021). Agrobiodiversity: A critical component of sustainable food systems. *Current Opinion in Environmental Sustainability*. **51**: 38-44.
- Kujur, A.N., Barla, S. and Upasani, R.R. (2026). Climate-smart agriculture: A pathway to food security and climate resilience- A review. *Agricultural Reviews*. **47**(3): 446-450. doi: 10.18805/ag.R-2777.
- Lebot, V. and Viquez-Zamora, C. (2025). Constraints to participatory plant breeding and participatory variety selection of tropical root and tuber crops: A review. *Euphytica*. **221**: 111. <https://doi.org/10.1007/s10681-025-03561-0>.
- Lemchi, J., Ogbonna, M. and Chukwu, G. (2016). Youth perspectives on traditional agriculture: A case study from Nigeria. *Agricultural Systems*. **145**: 102-110.
- Li, X. and Siddique, K.H.M. (2020). Future Smart Food: Harnessing the potential of neglected and underutilized species for zero hunger. *Maternal and child nutrition*. **16**(Suppl 3): e13008. <https://doi.org/10.1111/mcn.13008>.
- Lichun, H., Denita, H., Naalamle, A., Marcin, N., Sarah, L., Margaret, S., Nianjun, T. and Robert, N. (2018). Characterization of fifteen microsatellite loci and genetic diversity analysis for the Ghanaian food security crop *Solenostemon rotundifolius* (Frafra potato). *African Journal of Biotechnology*. **17**(47): 1352-1357. <https://www.semanticscholar.org/paper/815843c21551031ace498a9a84f1f954b75d6b7e>.
- Mabhaudhi, T., Chimonyo, V., Hlahla, S., and Massawe, F. (2019). Prospects of orphan crops in climate change. *Planta*. **250**(3): 695-708. <https://link.springer.com/article/10.1007/s00425-019-03129-y>.
- Mabhaudhi, T., Chivenge, P., Mabhaudhi, R. and Modi, A.T. (2019a). Food Security and Nutrition: The Role of Neglected and Underutilized Crop Species. In: *Encyclopedia of Food Security and Sustainability*. Elsevier. **2**: 126-133.
- Mabhaudhi, T., Hlahla, S., Chimonyo, V., Henriksson, R., Chibarabada, T., Murugani, V., Groner, V., Tadele, Z., Sobratee, N., Slotow, R., Modi, A., Baudron, F. and Chivenge, P. (2022). Diversity and diversification: Ecosystem services derived from underutilized crops and their co-benefits for sustainable agricultural landscapes and resilient food systems in Africa. *Frontiers in Agronomy*. **4**(4): 859223. <https://www.frontiersin.org/articles/10.3389/fagro.2022.859223/full>.
- Massawe, F., Mayes, S. and Cheng, A. (2020). Crop diversification: A tool for food and nutrition security and climate resilience in Africa. *Sustainability*. **12**(7): 2680.
- Mattalia, G., McAlvay, A., Teixidor Toneu, I., Lukawiecki, J., Moola, F., Asfaw, Z. A. Z., Cámara Leret, R. et al. (2024). Cultural keystone species as a tool for biocultural stewardship. A global review. *People and Nature*. **7**(5): 947-959. <https://besjournals.onlinelibrary.wiley.com/doi/10.1002/pan3.10653>.
- Manjeet, A., Niwas, R., Khichar, M.L. and Kumar, A. (2023). Study of climate change impact on crops and soil health in India: A review. *Agricultural Reviews*. **44**(3): 357-363. doi: 10.18805/ag.R-2200.
- Mayes, S., Massawe, F., Alderson, P.G., Roberts, J.A., Azam-Ali, S. and Hermann, M. (2012). The potential for underutilized crops to improve security of food production. *Journal of Experimental Botany*. **63**(3): 1075-1079. <https://academic.oup.com/jxb/article-lookup/doi/10.1093/jxb/err396>.
- Melash, A.A., Bogale, A.A., Migbaru, A.T., Chakilu, G.G., Percze, A., Ábrahám, É.B. and Mengistu, D.K. (2023). Indigenous agricultural knowledge: A neglected human based resource for sustainable crop protection and production. *Heliyon*. **9**(1): e12978. <https://doi.org/10.1016/j.heliyon.2023.e12978>.
- Meyer, R.S. and Purugganan, M.D. (2013). Evolution of crop species: Genetics of domestication and diversification. *Nature Reviews Genetics*. **14**(12): 840-852.
- Mgwenya, L.I., Agholor, I. A., Ludidi, N., Morepje, M.T., Sithole, M. Z., Msweli, N.S. and Thabane, V.N. (2025). Unpacking the multifaceted benefits of indigenous crops for food security: A review of nutritional, economic and environmental impacts in Southern Africa. *World*. **6**(1): 16. <https://doi.org/10.3390/world6010016>.
- Mmbando, G.S. (2025). The current challenges and solutions on utilizing the potential of underutilized and neglected crops for Africa's food security. *Discov. Plants*. **2**: 163. <https://doi.org/10.1007/s44372-025-00261-w>.

- Modest, R.B., Msalya, G., Nyomora, A.S. and Massawe, F. (2021). From indigenous knowledge to genomics: Unlocking the potential of African orphan crops. *Plants*. **10(2)**: 356.
- Molotoks, A., Smith, P. and Dawson, T. (2020). Impacts of land use, population and climate change on global food security. *Food and Energy Security*. <https://onlinelibrary.wiley.com/doi/10.1002/fes3.261>.
- Mphande, W. (2025). Research gaps in neglected indigenous vegetables in sub-Saharan Africa: A roadmap to mainstreaming. *Journal of Underutilised Crops Research*. **4(1)**: a33. <https://doi.org/10.4102/jucr.v4i1.33>
- Ngonzi, W. and Lubega, G. (2020). Threats to Indigenous Knowledge in Improving Agricultural Productivity in Crop Production of Kabasekende Sub-County, Kibaale District.
- Ohlin, G., Trueb, L., Raven, M. and Robinson, D.F. (2024). Towards a Fairer and More Equitable Bushfoods Industry: access and benefit-sharing and certification frameworks. *Australian Geographer*. **55(3)**: 309-327. <https://doi.org/10.1080/00049182.2024.2357790>.
- Razifard, H., Ramos, A., Valle, A.L.D., Bodary, C., Goetz, E., Manser, E., Li, X., Zhang, L., Visa, S., Tieman, D., Knaap, E. van der and Caicedo, A. (2020). Genomic evidence for complex domestication history of the cultivated tomato in latin America. *Molecular Biology and Evolution*. **37(4)**: 1118-1132. <https://academic.oup.com/mbe/article/37/4/1118/5679792>.
- Saensouk, P., Saensouk, S., Boonma, T., Ragsasilp, A., Junsongduang, A., Chanthavongsa, K. and Jitpromma, T. (2025). Plant species diversity and the interconnection of ritual beliefs and local horticulture in heet sip song ceremonies, roi Et Province, Northeastern Thailand. *Horticulturae*. **11(6)**: 677. <https://doi.org/10.3390/horticulturae11060677>.
- Smith, M. and Maunder, E. (2022). Nutritional diversity and food composition of African traditional crops. *Journal of Nutrition and Food Sciences*. **12(3)**: 1-9.
- Sperling, L., McGuire, S. and Ashby, J.A. (2020). Seed systems and resilience: The role of participatory varietal selection. *Outlook on Agriculture*. **49(1)**: 61-70.
- Tadele, Z. (2019). Orphan crops: Their importance and the urgency of improvement. *Planta*. **250(3)**: 677-694. <https://link.springer.com/article/10.1007/s00425-019-03210-6>.
- Termote, C., McMullin, S. and Prasad, H. (2021). From discovery to food system diversification with African neglected and underutilized species. pp. 78-87. <https://www.taylorfrancis.com/chapters/edit/10.4324/9781003044802-7/discovery-food-system-diversification-african-neglected-underutilized-species-c%C3%A9line-termote-stephamcmullin-hendre-prasad>.
- Thakur, M. (2014). Underutilized food crops: treasure for the future India. *Food Science Research Journal*. **5(2)**: 174-183. [http://researchjournal.co.in/online/FSRJ/FSRJ%205\(2\)/5_174-183_A.pdf](http://researchjournal.co.in/online/FSRJ/FSRJ%205(2)/5_174-183_A.pdf).
- Woldeyohannes, A.B., Iohannes, S.D., Miculan, M., Caproni, L., Ahmed, J.S., Sousa, K. de, Desta, E.A., Fadda, C., Pè, M.E. and Dell'Acqua, M. (2022). Data-driven, participatory characterization of farmer varieties discloses teff breeding potential under current and future climates. *Elife*. **2(11)**: e80009. <https://doi.org/10.7554/elife.80009.sa2>.
- Zerihun J. (2022). Production, challenges, potential and prospects of oromo potato (*Plectranthus edulis*) and anchote (*Coccinia abyssinica*) in Ethiopia: A review. *Agricultural Reviews*. **43(3)**: 348-354. doi: 10.18805/ag.R-178.