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Promoting Underutilized Legumes for Food Security to Small-Scale Farming Communities: Evidence from Developing Countries and Genetic Diversity Perspectives

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ABSTRACT

Food security remains a critical challenge in many developing countries, where small-scale farming communities rely heavily on staple crops with limited nutritional diversity. Promoting underutilized legumes (ULs) presents a viable strategy to enhance food security and resilience among these communities. Evidence from Sub-Saharan Africa, South Asia, and Latin America demonstrates that these crops improve soil fertility, increase crop diversity, and enhance household nutrition and income. Information was collected by using terminologies such as neglected or underutilized legumes, opportunity legumes, food secured crops from Google scholar, Scopus, PubMed, Semantic Scholar, Academia and research gate. Seventeen resilient ULs from over 114 peer-review articles and websites were collected, contributing to small-scale farming communities in food security, health and resilience from both agronomic and genetic diversity perspectives. The paper highlights the nutritional benefits, agronomy and environmental resilience, enhance genetic diversity for crop resilience of ULs. The evidence suggested that integrating ULs into small-scale farming systems can diversify diets, improve soil health and provide a buffer against climatic and economic risks. Furthermore, the conservation and utilization of genetic diversity within these legumes germplasms is crucial for breeding programs aimed at improving crop traits such as drought tolerance, disease and pest resistance and nutritional qualities. However, research gaps such as lack of awareness, limited market access, and quality seed availability hinder their widespread adoption. Policy recommendations include supporting local seed systems, investing in agricultural research, and fostering community-based approaches to promote the adoption of underutilized legumes. This approach will not only strengthen food security but also enhance the sustainability and resilience of small-scale farming communities in developing countries.

Keywords: food security, genetic diversity, small-scale farming, underutilized legumes

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RÉSUMÉ
La sécurité alimentaire demeure un défi critique dans de nombreux pays en développement, où les communautés agricoles de petite taille dépendent de cultures de base à diversité nutritionnelle limitée. La promotion des légumineuses sous-utilisées (LSU) offre une voie tangible pour accroître la sécurité alimentaire et la résilience. Les données issues d'Afrique subsaharienne, d'Asie du Sud et d'Amérique latine montrent que ces cultures améliorent la fertilité des sols, augmentent la diversité culturale et renforcent la nutrition et les revenus des ménages. Cette étude a examiné ces problêmes en mobilisant des descripteurs tels que les légumineuses négligées/sous-utilisées, les légumineuses d'opportunité, les cultures de sécurité alimentaire dans Google Scholar, Scopus, PubMed, Semantic Scholar, Academia et ResearchGate. Dix-sept LSU résilientes ont été recensées à partir de plus de 114 articles évalués par les pairs et de sources web, mettant en évidence leurs contributions à la sécurité alimentaire, à la santé et à la résilience des petites communautés agricoles, sous les angles agronomique et de la diversité génétique. L'article met en exergue les bénéfices nutritionnels, l'aptitude agronomique et la résilience environnementale des LSU, ainsi que l'enrichissement de la diversité génétique, gage de résilience des cultures. Les éléments rassemblés indiquent que l'intégration des LSU dans les systèmes de petite agriculture diversifie les régimes, améliore la santé des sols et constitue un tampon face aux risques climatiques et économiques. Par ailleurs, la conservation et l'utilisation de la diversité génétique au sein des germoplasmes de ces légumineuses sont cruciales pour des programmes d'amélioration ciblant la tolérance à la sécheresse, la résistance aux maladies et ravageurs et la qualité nutritionnelle. Des lacunes persistent : manque de sensibilisation, accès limité au marché et disponibilité insuffisante de semences de qualité. Les recommandations incluent le soutien aux systèmes semenciers locaux, l'investissement dans la recherche agricole et la promotion d'approches communautaires pour l'adoption des LSU. Cette orientation renforcerait la sécurité alimentaire tout en améliorant la durabilité et la résilience des petites exploitations.

Mots clés: sécurité alimentaire ; diversité génétique ; petites exploitations ; légumineuses sous-utilisées

INTRODUCTION

Food security remains a critical challenge for many developing countries, particularly in rural areas where small-scale farming is the primary means of their livelihood. Traditional agricultural practices, often dominated by staple crops such as maize, rice, sorghum, and wheat, have struggled to meet food access, nutrition and economic needs of rural communities. Considering the climate change impacts and significance of the future smart and sustainable foods, neglected and underutilized species are the best choice for the rapid global population, particularly in lower income countries (Ebert, 2014; Talucder *et al*., 2024). This scenario calls for innovative approaches to enhance agricultural productivity, diversify diets, and ensure sustainable farming practices by ensuring crop diversification using neglected crop, is a practical strategy that can greatly improve household food security and economic well-being (Adula *et al*., 2023). Neglected and underutilized species are those associated with traditional farming knowledge to which have limited scientific knowledge (Gruère *et al*., 2006), and had little attention or which are entirely ignored by agricultural researchers, plant breeders and policymakers (Odeku *et al*., 2024), but they support more to climate resilient and healthful food systems in developing countries (van Zonneveld *et al*., 2023). Likewise, Padulosi *et al*. (2013) highlighted that neglected and underutilized crops present tremendous opportunities for fighting poverty, hunger and malnutrition, to achieve the United Nations Sustainable Development Goals (SDGs). In light of these goals, legumes are the most resilient, scalable and have promising solutions. However, not all beneficial legumes are under exploration, rather they are underutilized. Therefore, exploring wild and underutilized legumes could be of high significance for food security, meeting nutritional requirements, crop diversity, and agricultural developments. This could be an efficient means for rotation of crops, and thus can effectively contribute to the overall improvement of a nation's economy (Bhat and Karim, 2009).

According to Talucder *et al*. (2024), plant species that are investigated and recorded as neglected and underutilized species diversity are from developing Asian and impoverished countries, followed by Africa. Legumes such as cowpeas (*Vigna unguiculata*), common beans (*Phaseolus vulgaris*), lablab beans (*Lablab purpureus)*, Adzuki bean (*Vigna radiata*), Kersting's groundnut (*Macrotyloma geocarpum*), Bambara groundnut (*Vigna subterranean*), lentils (*Lens culinaris*), chickpeas (*Cicer arietinum*), pigeon peas (*Cajanus cajan*), and mung beans (*Vigna angularis*) offer substantial benefits (de Freitas *et al*., 2012; Sehgal *et al*., 2017; Taboada *et al*., 2022; Dinkar *et al*., 2023; Samal *et al*., 2023). These legumes provide a vegetarian-based protein diet, and are abundant in proteins, vitamins and minerals that are vital to fight malnutrition, and improve general health in rural communities (Samal *et al*., 2023). Hence, they can also be considered as staple food crops for vegetarian people. Furthermore, ULs have the ability to fix atmospheric nitrogen, enhance soil fertility and reduce the dependency on chemical fertilizers, and promoting more sustainable farming practices (Lipper *et al*., 2014; Vanlauwe *et al*., 2019). Integrating these legumes into local farming systems not only improves soil health and crop yields but also provides a steady and diverse source of income for small-scale farmers (Stagnari *et al*., 2017; Vanlauwe *et al*., 2019).

Despite these advantages, the widespread adoption of ULs in developing countries faces several challenges, including limited awareness, limited market access, and limited improved quality seeds (Breen *et al*., 2024). For instance, Maphosa *et al*. (2022) highlighted that Bambara groundnut productivity affected by a range of disease such as leaf spot, fusarium wilt, cowpea aphid-borne mosaic virus, black-eye cowpea mosaic virus, peanut mottle potyvirus, and Rosette virus diseases and pests such as root-knot nematode, leafhoppers and *Empoasca facialis* (Jacobi), Aphids and groundnut jassid. Moreover, abiotic stresses such as e erratic rainfall, extreme temperature ranges (very high and low), altitude and poor soils together with socio-economic constraints affect Bambara groundnut productivity, yield and quality. Addressing these issues required targeted interventions such as capacity building and community outreach programs to raise awareness about the benefits and cultivation techniques of underutilized legumes. Additionally, improving market infrastructure and establishing local seed banks can ensure farmers have access to both markets and high-quality seeds. Policymakers and development organizations must support these initiatives to facilitate the integration of ULs into farming systems. By overcoming these barriers, the potential of underutilized legumes will fully realize in food security, nutrition, and sustainable agriculture in small-scale farming communities (Stagnari *et al*., 2017; Ayilara *et al*., 2022).

Encouraging advanced technologies on ULs for food security in small-scale farming communities through the lens of genetic diversity presents a compelling case for enhancing agricultural resilience and nutritional quality. Evidence from Asian and

African countries indicates that the species diversity found in underutilized legumes such as cowpeas, common bean, Bambara groundnut, lentils, chickpeas, pigeon peas, faba beans and mung beans provides a robust defense against pests, diseases, and environmental stresses (Popoola *et al*., 2023; Talucder *et al*., 2024). This genetic diversity enables these legumes to adapt to diverse and challenging growing conditions, thereby ensuring a reliable food source in areas frequently affected by climate change and soil degradation. By integrating a broad spectrum of legume species and landraces into their farming systems, small-scale farmers can reduce the risk of crop failure, enhance soil health through nitrogen fixation, and improve overall farm productivity (Abobatta *et al*., 2021).

Additionally, the genetic diversity of ULs contributes significantly to dietary diversity, which is crucial for addressing malnutrition and micronutrient deficiencies prevalent in many developing countries (Olanrewaju *et al*., 2022). Different legume species offer distinct nutrient profiles, providing essential proteins, vitamins, and minerals that complement the typically cereal-based diets of small-scale farming communities. However, the information on genetic resources and crop improvement research on ULs is limited although there have been some collections in India, Indonesia and Africa (Haq, 2011). Preserving the genetic resources of these crops is vital for sustaining agricultural biodiversity, which underpins long-term food security and ecosystem stability (Mal, 2007; Varaprasad and Sivaraj, 2010). Policy initiatives and development programs must prioritize the conservation and promotion of genetically diverse legume varieties, leveraging their full potential to bolster food security and enhance the resilience of small-scale farming communities with further advanced breeding programs.

METHODOLOGY

This review was conducted through a comprehensive literature review of the current status of ULs from Google scholar, Scopus (Elsevier), Web of Science, Semantic Scholar, Academia, Research gate, PubMed Central (PMC), peer-review articles and websites. To get relevant information, we used terminologies such as underutilized or neglected legumes, opportunity legumes, food secured crops, individual scientific names, nitrogen fixing crops. The literature analysis was done over 114 research articles and mainly focused on agronomical values, genetic resources, and their potential for sustainable food and nutrition values in developing countries. Additionally, a review of current advances in breeding techniques for improving these resilience underutilized legume crops and their sustainability was emphasized, and thus we collected and exploited previous studies enhance on the promoting ULs in developing countries context (Table 1).

Imperativeness of Underutilized Legumes (ULs) for Small-Scale Farming Communities. Why underutilized legumes so important? Underutilized legumes hold significant importance in developing countries, offering multifaceted benefits that contribute to sustain food security, nutritional diversity, environmental sustainability, and economic resilience (Olanrewaju *et al*., 2022). For example, pigeon peas are a staple food in parts of Africa and South Asia, providing a vital protein source and contributing to soil health through nitrogen fixation (Varshney *et al*., 2017; Dinkar *et al*., 2023). In Ethiopia, lentil is an underutilized legume, but has potential to improved food security and dietary diversity among the small-scale farming communities, due to its high nutritional value and adaptability to local growing conditions (Reda, 2015). In India, Bambara groundnut often grown on marginal lands, has become an essential crop for smallholders due to its drought resistance and ability to thrive in poor soils (Singh and Basu, 2005). This indicates that, these legumes not only enhance agricultural biodiversity but also offer economic opportunities through niche markets and value-added products. By integrating the ULs into the developing countries, community farming systems, can achieve more resilient and sustainable agricultural practices, ensuring better nutrition and livelihoods of the populations.

Nutritional Benefits. The health advantages of replacing animal-based proteins with plant-based proteins have come to light in recent years, particularly in developed countries (Baby *et al*., 2023). Legumes are vital sources of plant-based proteins, which are necessary for effective metabolism and human wellbeing (Ikhajiagbe *et al*., 2022). They are repository of vital nutrients that provides carbohydrates, proteins, energy, crucial amino acids, minerals and vitamins to developed and low-income countries where animal proteins are not readily available (Ebert, 2014; Khan *et al*., 2021; Maphosa *et al*., 2022; Baby *et al*., 2023). Notably, ULs are nutritional powerhouses, offering a health promoting components. They play a vital role in combating malnutrition and dietary deficiencies, which are prevalent in many developing countries (Olanrewaju *et al*., 2022; Ramatsetse *et al*., 2023), and considered as high-protein food sources. For instance, adzuki bean (*Vigna radiata)* is one of the neglected and underutilized legume crops, and native to East Asia, has important sources of manganese (Mn), iron (Fe), and zinc (Zn), which are essential in many metabolic reactions as co-factors for different enzymes, and pharmacological properties (Jain *et al*., 2021). Additionally, Bambara groundnut (*Vigna subterranea*) and velvet beans (*Mucuna pruriens*) are among the imperative and neglected legume crops that contribute positively to improving global food and nutrient safety. Likewise, winged bean (*Psophocarpus tetragonolobus*) has huge potential to become an important multi-use food crop in the tropics of Asia and other parts of the world (Sunani *et al*., 2021); likely, jack bean (*Canavalia ensiformis*) has also a great potential as food self-sufficiency in Indonesia's sub-optimal land, and supplement the demand of soybean and rice (Darini *et al*., 2021). Thus, for small-scale farming communities, ULs provide an affordable and accessible source of high-quality nutrition, complementing carbohydrate-heavy diets typical in these areas. Their consumption can lead to improved health outcomes, particularly for children and pregnant women, who are most vulnerable to nutritional deficiencies.

The ULs offer a dual benefit by providing both seeds and leafy vegetables, which are rich in essential nutrients. Immature pods and leaves of legumes such as from those cowpeas, peas, beans, pigeon peas, and lablab beans, are highly nutritious, containing significant amounts of vitamins A, C, and K, as well as minerals like calcium (Ca), iron (Fe), and potassium (K) (Dhaliwal, 2017; Mekonnen *et al*., 2022). Consuming these leafy vegetable legumes can provide a substantial nutritional boost, particularly in regions where access to a diverse range of food sources is limited. For instance, cowpea leaves are widely consumed in various parts of West Africa, where they are often cooked and incorporated into stews and soups, contributing to the dietary diversity and nutritional intake of local communities (Hallensleben *et al*., 2009; Owade *et al*., 2020).

In addition to their nutritional values, the consumption of legume leaves as vegetable promotes sustainable agricultural practices by utilizing the entire plant and reducing waste. This approach is especially beneficial in small-scale farming communities, where maximizing the use of available resources is crucial for food security and economic resilience. For example, pigeon pea leaves are not only used as a leafy vegetable but also as fodder for livestock, demonstrating their versatility and importance in integrated farming systems (Saxena *et al*., 2010; Snapp *et al*., 2003). By growing ULs, for both their seeds and leaves, small-scale farmers can improve their lifestyle through overall productivity and income, making their agricultural practices more sustainable and economically viable.

Furthermore, the integration of UL leaves into diets can enhance food security and nutrition in vulnerable populations. For instance, in South Asia, the leaves of the lablab bean (*Lablab purpureus*), locally known as hyacinth bean, are consumed as a green leafy vegetable (Maass, 2016; Swamy, 2023). These leaves are rich in antioxidants and have been traditionally used in local cuisines to prepare various dishes (Maass, 2016; Naeem *et al*., 2020). By promoting and integrating the consumption of some UL leaves, small-scale farming communities can improve their nutritional status while preserving traditional culinary practices and biodiversity. This practice has also powerful to support health and well-being as well as strengthens the cultural heritage and food sovereignty of their livelihood.

The ULs also serve as a crucial fodder for animals in developing countries, providing an affordable and nutritious feed source,that supports livestock health and productivity. For instance, mung bean (*Vigna radiata*) is highly palatable legume than other fodders such as berseem (*Trifolium alexandrinum*) and alfalfa (*Medicago sativa*), and attracted by the livestock and even more nutritious in nature (Ullah *et al*., 2012). Likely, pigeon peas, cowpeas, Bambara groundnut and lablab beans are also highly valued for their high protein content suitable for livestock, ability to fix atmospheric nitrogen and environmental sustainability.

Furthermore, in many parts of Africa, India and Southeast Asia, such as cowpea, rice bean (*Vigna umbellate*) and Bambara groundnut leaves and haulm are commonly used as fodder, providing essential nutrients to livestock during the dry season when other feed sources are scarce (Adeloye, 1995; Dahipahle *et al*., 2017; Samireddypalle *et al*., 2017; Gerrano *et al*., 2021). Similarly, in Africa and India, lablab beans are used extensively as fodder due to their high biomass production and nutritional quality (Chakoma *et al*., 2016). Notably, these ULs not only enhance animal growth and milk production but also contribute to sustainable farming practices by reducing the need for commercial feed and fertilizers. Therefore, by integrating ULs into livestock feeding systems, small-scale farmers can improve the health and productivity of their animals, thereby increasing their overall agricultural efficiency and resilience.

On the other hand, some wild and ULs might have high potential to be used as human food and animal feed, along with providing information for overcoming malnutrition-associated problems and also for future commercial exploitation such as a source of nutraceuticals, for new food formulations, biofortification, and other products (Bhat and Karim, 2009). They might also offer information on how to address problems associated to malnutrition. Various processing techniques, including irradiation, germination, heating, and dry heat treatments, can overcome them (Bhat and Karim, 2009). For instance, germination of jack bean enhances its functional qualities; hence, a 72-hour germination period boosted the oil, water, and foaming capacities while decreasing the emulsion capacities (Kanetro *et al*., 2021).

Agronomic and environmental resilience. Currently, intensive farming systems reduce soil fertility, and once fertile soil becomes unproductive, severe degradation of the environment has occurred and consequently diminishes crop yields. ULs have significant positive impact on environment, farming societies, promoting sustainability and ecological health (Odeku *et al*., 2024). ULs are often used as a cover crops, and well adapted to a variety of agro-ecological conditions, including marginal soils and drought-prone areas (Popoola *et al*., 2023). This adaptability makes them invaluable for small-scale farmers who frequently operate in less-than-ideal farming environments. By using a cropping pattern, the ULs such as pigeon peas (Phiri *et al*., 2012), adzuki beans (Shahrajabian *et al*., 2019), cowpeas (Stoop, 1986; Ajeigbe *et al*., 2005), and winged bean (Maure *et al*., 2019) are some examples of resilient legume crops that can thrive where other crops cannot grow.

It is worth nothing that climate change affects our environment sustainability. The ULs provide a substantial contribution to environmental sustainability mitigation. Nearly all ULs have the capacity to mobilize atmospheric nitrogen in the soil, with the possible exception of variations in the type and degree of nitrogen-fixing ability. The nature of nitrogen fixation not only boosts crop yields but also promotes sustainable farming practices by minimizing chemical inputs and their associated environmental impacts. As a result, less chemical fertilizers will be required, which will lessen the possibility of soil and water contamination (Yuvaraj *et al*., 2020). For instance, Adu-Gyamfi *et al*. (2011) highlighted that Kersting's groundnut can fix over 80% of its nitrogen requirement, however fertilizer may be needed if the soil is damaged. Additionally, Furtado *et al*. (2011) highlighted that jack-bean and pigeon-pea are relevant for the recuperation of mine areas, especially in the presence of organic compost, by making the phosphorus available for other plants in the system. According to Adjei-Nsiah (2012), pigeon peas widely grown in regions like Africa and India, enhance soil health and facilitate sustainable crop rotations, as *pigeon peas-maize* rotations can increase maize yield by 75–200%.The deep rooting systems of many ULs improve soil structure, prevent erosion, and enhance water infiltration, particularly beneficial in areas prone to land degradation and drought (Yuvaraj *et al*., 2020). In East Africa, the cultivation of cowpea has been observed to improve soil moisture retention, thereby increasing resilience to dry conditions (Kebede and Bekeko, 2020). Additionally, incorporating these ULs into intercropping systems boosts biodiversity, reduces pest and disease pressures, and minimizes the reliance on chemical pesticides. Impressively, this integrative approach not only enhances agricultural productivity, but also contributes to environmental conservation (Kumawat *et al*., 2022; Odeku *et al*., 2024). Consequently, ULs play a crucial role in fostering sustainable farming practices and ecological balance in small-scale farming communities across developing countries.

Economic benefits. Farming societies neglect their indigenous knowledge, local and wild crop types, and substitute by alternative and sustainable crops due to different agricultural intervention technologies across the world. Nevertheless, ULs usually have deep cultural and social significance within the small-scale farming communities. They are frequently integral to traditional diets, culinary practices, and local customs (Lisciani *et al*., 2024). For instance, Onuche *et al*. (2020) highlighted that bambara groundnut production can be made profitable through labour cost reduction and improvement in average efficiency level by 28.8%. In Ethiopia, farmers produced common bean got an average revenue of \$400 $^{-1}$ ha from grain yield (Fikadu *et al*., 2020), and Nigeria is the largest producer of cowpea in the world, with a total production of 3.6 million tons in 2021, the demand for cowpea surpasses its supply due to factors such as the country's large population and low productivity (Nwagboso *et al*., 2024). Conversely, the contribution of ULs to food and nutrition security is still limited due to socio-economic challenges faced by farmers (lack of credit), leading to overreliance on a few legumes with poor resilience to climatic perturbations, thus posing a risk to sustainable food production (Vilakazi *et al*., 2025). Hence, promoting the cultivation and consumption of these legumes help to preserve cultural heritage and traditional knowledge of farming societies, fostering a sense of community and identity. Involvement of local communities (participating farmers or participatory plant breeding) in the promotion and conservation of underutilized legumes can strengthen societies and empower farmers, particularly women, who are often key custodians of agricultural biodiversity and traditional food systems (Pschorn-Strauss, 2013).

The ULs provide additional income streams for small-scale farming communities. Their cultivation and sale can diversify farm income, reducing dependence on a single crop and spreading financial risk. The local and regional markets for these legumes are often less saturated than those for more common crops, providing opportunities for farmers to capitalize on niche markets. Furthermore, the processing and value addition of ULs into products such as flour, snacks, and animal feed can create new entrepreneurial opportunities within farming communities (Onyango, 2017). By developing these value chains, small-scale farmers can increase their income and economic resilience.

Furthermore, ULs offer substantial economic benefits for small-scale farming communities, providing diverse income streams and enhancing financial stability. For instance, in regions like West Africa, cowpeas are not only sold as fresh or dried beans but also processed into various value-added products such as flour, snacks, and animal feed, creating new market opportunities and increasing farmers income (Otoo *et al*., 2010; Otoo, 2011), which is nowadays practiced imperative research in cowpea interventions. In addition, common bean value added technologies for enhancing food security, nutrition, income and resilience to cope with climate change and variability challenges in eastern Africa was examined (Karanja *et al*., 2011). Similarly, Kersting's groundnut is an important source of income for stakeholders involved in its value chain in West Africa (Agoyi *et al*., 2019). Therefore, market linkages among actors along the beans value chain should be established through an innovation platform. However, the local and regional demand for these ULs is often less saturated compared to major staple crops, allowing farmers to capitalize on niche markets and obtain better prices.

Genetic diversity and crop resilience. Legumes in general play a prominent role in human and animal diets, sustainable crop production and fostering biodiversity-based agriculture. However, their implication to the human food supply and security, their genetic diversity is underestimated (Icka *et al*., 2023). The genetic diversity inherent in ULs is a valuable resource for breeding programs aimed at improving crop resilience. This diversity can be harnessed to develop new resilient varieties that are more resistant to pests, diseases, and environmental stresses. Impressively, sustainable resource management coupled to resilient germplasm to provide new intensive *cereal–grain–legume–livestock* systems in the dry savanna (Sanginga *et al*., 2003). By preserving and utilizing the different types ULs genetic resources (germplasms), researchers, stakeholders, farmers, policy makers can work together to develop more robust agricultural systems such as drought tolerance, disease resistance, market-oriented class varieties, value-add systems, and nutritional qualities (Table 1).

Table 1. A description summary of seventeen resilient underutilized legumes and their functional properties with their respective references.

S. N	Common name	Botanical name	Country of origin	Growth habit	Economical part of the legume	Desirable agronomic traits	Undesirable agronomic traits	Intervention breeding practices	List of developing countries under domesticated/cultivated ULs	References
1	Adzuki beans	*Vigna angularis*	East Asia	Annual with bushy, climbing and spreading growth habit	Seed and leaves	Strong root system, anti-inflammatory, and anti-hypertensive	Hard seed coat, sensitive to low T^0c, poor competitor to weeds	Conventional breeding, QTL, MAS, genomics	DR Congo, Kenya, Angola, Zambia, Madagascar and Seychelles	(Kaga *et al*., 2008; Haq, 2011; Popoola *et al*., 2023; Torabian *et al*., 2021)
2	African yam bean	*Sphenostylis stenocarpa*	Central and western Africa	Annual and climbing growth habit	Both seeds and tuber	Has large genetic variation, high fiber content, and bioactive compounds	Hard-to cook	Conventional breeding and nutritional composition assessments	Nigeria, Ghana, Benin, Cameroun, Togo, Niger, Kenya, Ethiopia, Mozambique and Tanzania.	(Adewale and Nnamani, 2022; George *et al*., 2020; Haq, 2011; Nwosu, 2013; Popoola *et al*., 2023)
3	Bambara ground nut	*Vigna subterranea*	North-Eastern Nigeria and Northern Cameroon	Annual with bushy and spreading habit and geocarpic	Immature seeds, pods and dried seeds	Used for traditional medicine, and is drought tolerance	Hard-to cook, presence of ant-nutritional compounds (cpds) in the dry seed	Characterization and participatory breeding, diversity analysis	Nigeria, Ghana, Niger, Mali, Cote d'Ivoire, Benin, South Africa and Kenya.	(Gerrano *et al*., 2021; Haq, 2011; Popoola *et al*., 2023)
4	Cowpea	*Vigna unguiculata*	East and west Africa	Climbing, bushy and spreading	All aerial parts (leaf, seed, pod, tender shoots,haulm)	Drought resistant, Nitrogen fixer	Anti-nutritional cpds, Susceptible to insects	Genomics, CRISPR/Cas9, population genetic structure	Grow in all Sub-Saharan African countries, predominantly in West African countries	(Herniter *et al*., 2020; Ji *et al*., 2019)
5	Faba bean (Broad bean, horse bean)	*Vicia faba*	Middle east (Israel)	Annual, erect position with tillering capacity, indeterminate and determinate growth habit	Fresh pods, and dry seeds	Sources of partial resistance to main diseases (ascochyta blight, rust, chocolate spot and gall diseases)	Anti-nutritional cpds, frost sensitive, limited genetic diversity	Comparative genomic selection, MAS, vicine-convicine quality gene discovery	Algeria, Egypt, Tunisia, Morocco, Ethiopia	(Adhikari *et al*., 2021; Östberg, 2021)
6	Horse gram	*Macrotylema uniflorum*	South-east Asia, Hindustan	Annual, Herbs with twining branches	Seeds, leaves	Forage, resilience to drought, heavy metals stresses, salinity, infertile soils	Poor cooking quality, presence of high levels of enzyme	Conventional crossing,	African and Asian countries	(Jain *et al*., 2021; Haq, 2011)

							inhibitors and haemagglutinin activities			
7	Jack bean	*Canavalia ensiformis*	West India and central America	Annual/perennial, climbing, bushy erect and semi-erect growth habit	All aerial parts (leaf, tender shoots, pods and seeds	Seeds used as antibiotic and antiseptic, Phytoremediation, Soil biofumigant	Hard-to-cook, not feed by animals	Conventional breeding	Western, Eastern and Northern Africa	(Lenkala *et al*., 2015; Haq, 2011;Popoola *et al*., 2023, 2023; Purwandari *et al*., 2023, 2024)
8	Kersting's groundnut	*Macrotyloma geocarpum*	Northern Togo and central Benin	Annual and geocarpic	Seeds, fresh leaves and its stover	Rich in amino acids, palatability, black and brown seeds are resistant to Bruchid	Sensitive to long-lasting rainfall, low yield, white seeds are susceptible to bruchid, has anti-nutritional compositions	Morphological, biochemical, and molecular markers (SSRs & SNPs) characterizations	West African countries (Benin, Burkina Faso, Ghana, Nigeria, Togo, and Senegal), Cameron, Tanzania and Mauritius	(Coulibaly *et al*., 2022; Tele Ayenan and Ezin, 2016)
9	Kidney bean (Commone bean, Pinto bean)	*Phaseolus vulgaris*	Peru	Annual, bushy, climbing and spreading	Dry seeds, and immature pods	Has bioactive compounds	Sensitive to bruchids and anthracnose,photoperiod-sensitive and hard-to-cook	DNA markers, Genome editing	Western, Eastern and Northern African countries	(Gomes-Messias *et al*., 2022; Peer *et al*, 2023; Popoola *et al*., 2023)
10	Lablab (Dolichos bean)	*Lablab purpureus*	Africa or India (It is in debate)	Annual and perennial, erect and semi-erect bushy bean	Dry and green seeds including immature pods	Has vigorous taproot,	Has a peculiarly strong and unpleasant smell, sensitive to bruchid	Genetic diversity, conventional breeding, DNA markers	Nigeria, Tanzania, Kenya and Ethiopia	(Swamy, 2023; Letting *et al*., 2021, 2022; Haq, 2011)
11	Lima bean	*Phaseolus lunatus*	Lima Peru	Perennial, annual, bushy erect and and vining types	Sprouts, leaves, young pods and green seeds (immature or dry)	Drought resistant	Raw seeds have toxicity, lack of uniform seed size, shape and color	Morphological descriptors, biochemical, and microsatellite, ISSR markers,	Western, Eastern and Northern African countries	(Nasir *et al*., 2021; Nazmul Haq, 2011; Popoola *et al*., 2019)
12	Marama bean (Green gold of Africa or Gemsbok bean)	*Tylosema esculentum*	Southern Africa	Perennial	Seeds and tubers	Drought and heat resistant, moisture resistance, potential seeds to produce oil, milk and flour	Lack of nodulation	Comparative analysis, physicochemical characterization, DNA Markers, SNPs, InDels,	Botswana, Ethiopia, Angola, Namibia, Mozambique, Zambia and northern South Africa	(Afolayan and Orijajogun, 2024; Li and Cullis, 2023; Popoola *et al*., 2023)

13	Mung bean	*Vigna radiata*	India	Annual, erect and semierect,	Dry bean and sprouts	Has sturdy taproot	Susceptible to bruchid,	QTL mapping, MAS, Genomics and transcriptomics	Nigeria, Liberia, Sierra Leone, Ghana, Cote d'Ivoire, DR Congo, Kenya, Tanzania and Uganda	(Haq, 2011; Popoola *et al*., 2023; Sequeros *et al*., 2021)
14	Pigeon pea	*Cajanus cajan*	North-Eastern Africa	Perennial,	Dry seeds and leaves	Drought resistant, erosion control, as medicinal drug including anti-cancer activity	Frost sensitive, low yield, lack of quality seeds	Botanical description, MAS and de novo genome sequencing	Kenya, Uganda and Malawi	(Dinkar *et al*., 2023; Pal *et al*., 2011; Varshney *et al*., 2017)
15	Rice bean (red bean or mambi bean)	*Vigna umbellata*	Indo-China	Annual and perennial, Climbing, erect and semi-erect	Seed	Resistant to pests and Aluminum toxicity, culinary purpose and antioxidant activity and antidiabetics activity	Late flowering, photoperiod sensitivity, indeterminate nature, hard seededness, susceptible to fungi diseases	Domestication syndrome, QTLs, DNA markers, genetic linkage map	Egypt, Kenya, Tanzania, Burundi, Somalia and Rwanda	(Francis *et al*., 2023; Isemura *et al*., 2010; Haq, 2011; Pattanayak *et al*., 2019; Popoola *et al*., 2023)
16	Velvet bean	*Mucuna pruriens*	Asia	Annual, perennial Climbing, bushy, erect, semi-erect	Immature pods, leaves, dry seeds	Reasonable tolerance drought, low soil fertility, and high soil acidity	Anti-nutritional factors, pubescence cause itching sensitive to frost and grow poorly in cold and wet soils	Conventional breeding, genetic diversity,	West African countries, India, Indonesia	(Baby *et al*., 2023; Hemkumar *et al*., 2023; Lampariello *et al*., 2011; Haq, 2011)
17	Winged bean (dragon bean or Asparagus bean)	*Psophocarpus tetragonolobus*	India	Annual or perennial vine	All part of the plant, including the tuberous roots	Has quality edible oil, rich in protein content	Has anti-nutrient cpds, indeterminate plant habit	Genomic, transcriptomic and metabolomic	Papua New Guinea Highland, northern Ghana and Burma Nigeria, Togo and Benin	(Mohanty *et al*., 2020; Haq, 2011; Sriwichai *et al*., 2021; Tanzi *et al*., 2019)

Different national and international conservation gene banks of legumes are found in different countries. Globally, over 0.7million legume germplasms, including their crop wild relatives (CWRs), are conserved in 276 gene banks distributed worldwide (Gayacharan *et al*., 2023). For instance, the Indian National gene bank conserves over 63,000 accessions of legumes belonging to 61 species. Recent initiatives have been undertaken in consortia mode with the aim of unlocking the genetic potential of ex-situ collections and conducting large-scale germplasm characterization and evaluation analyses (Gayacharan *et al*., 2023). This implies that genetic diversity is not only enhancing the resilience of individual crops, but also contributing to the overall stability of the agricultural ecosystem, ensuring long-term food security for small-scale farming communities. Gore *et al*. (2022), highlighted that identifying promising accessions can be utilized in underutilized Indian legume improvement program through introgression breeding and/or can be used for domestication and enhanced utilization of the crop.

Additionally, there are also some other legume germplasm Gene banks across the international repositories. For instance, The International Institute of Tropical Agriculture (IITA) gene bank holds the world's largest and most diverse collection of cowpeas with 15,000 unique samples from 88 countries, representing 70% of African cultivars and nearly half of the globaldiversity(https://www.iita.org/research/genetic-resource/). Similarly, over 5,000 accessions of adzuki bean germplasm had been collected and conserved at the National Gene Bank of China (Wang *et al*., 2012), and up to 6,145Bambara groundnut landraces/accessions are also conserved in ex-situ, and these collections are kept in trust by international or regional gene banks, which are comprised of several countries (Muhammad *et al*., 2020). Furthermore, the International Center for Tropical Agriculture (CIAT) holds the largest *Phaseolus* collection (Common beans), with almost 40,000 accessions, followed by the United States Department of Agriculture-Agricultural Research Service (USDA-ARS) gene banks with nearly 18,000 samples and the Leibniz-Institut für Pflanzengenetik und Kulturpflanzenforschung (IPK) with more than 10,000sampleshttps://www.genbanks.org/resources/crops/beans/). There are also some African yam beans (AYB) germplasm resources have been conserved in national and international institutes, about ≤ 600 AYB accessions at the IITA, Ibadan, Nigeria, holds the largest (450 resources) conservation of the crop, but some still exists as not conserved landraces (Adewale and Abberton, 2024).

According to Sprent *et al*. (2010), African ULs are particularly important resources for future research and development as well as for maintaining agricultural diversity, which is critical for a changing global food system. Likely, ULs play a pivotal role in enhancing genetic diversity and bolstering crop resilience. ULs most likely have a major impact on increasing crop resilience and genetic diversity, which are crucial factors in sustainable agriculture and food security. Adzuki beans, lima beans, rice beans, pigeon peas, African yam beans, cowpeas, and Bambara groundnuts are examples of legumes that have a diverse of genetic traits that allow them to adapt to a range of agro-ecological circumstances and environmental stressors. Research on these genetic resources is still lacking, and maintaining and utilizing them remains a difficult task (Bauchet *et al*., 2019). This can be leveraging by integrating genomics, phenomics and othet breeding tools which is widely applicable to other staple food crops such as maize (Adak *et al*., 2023) and wheat (Robert *et al*., 2022), but not yet applied to ULs. This could overcome the time taken for getting improved cultivars in the targeted breeding programs.

The genetic variability of ULs supports the development of climate-resilient agricultural systems (Jha *et al*., 2022), i.e., crucial in the face of climate change impacts such as erratic rainfall patterns and rising temperatures. Incorporation of the diverse but underutilized legume species into cropping systems enhances agro-biodiversity, promoting ecosystem health and resilience. There are progressive breeding programs in Sub-Saharan Africa focused on enhancing the resilience of cowpea to pests and diseases, ensuring more stable yields and reduced crop losses (Boukar *et al*., 2018; Togola *et al*., 2023). For instance, in West Africa, there are projects focused on building resilient seed systems, developing nutrition enhancement genetic materials of cowpea at the International Institute of Tropical Agriculture (IITA) through genomics and other omic tools. Similarly, in East Africa, particularly the Uganda cowpea breeding program has an initiative projects in developing disease and pest resistance, drought tolerant, high yielding varieties, and screening potential cowpea lines for biological nitrogen fixation (BNF) and GWAS in BNF related traits for small-scale farmers. Overall, the conservation and utilization of genetic diversity within ULs are essential strategies for strengthening crop resilience, improving food security, and fostering sustainable agricultural practices in developing countries**.**

A summary of review on the seventeen ULs is described their desirable and undesirable agronomic traits in terms of origin, breeding, agronomic practices and economic used parts with their respective references in Table 1. Majority of the ULs have antinutritional components (*e.g*., Bambara groundnut and faba bean), hard to cook (consumes high energy) (*e.g*., jack bean, African yam bean and Adzuki bean), susceptible to bruchid insect (*e.g*., cowpea, mung bean, lablab bean, Kersting's groundnut) and anthracnose disease (*e.g*., kidney bean), photoperiod sensitivity (*e.g*., rice bean), lack of nodulation (*e.g*., marama beans). Additionally, there is no standard cooking time and digestibility (palatability) of the UL beans. This indicted that intensive nutrition enhancement breeding programs is necessarily needed for all these ULs overall the small-scale farming communities in the developing countries, by considering their economical and food resilience perspectives.

CONCLUSIONS AND RECOMMENDATIONS

This review paper is assessed on ULs research gaps such as presence of limited research programs, limited integration policy recommendations and lagged in advanced genomics researches such as phenomics, CRISPR-Cas9, GWAS, which is so far abundantly applied in major staple crops; however, created a stagnant in nutritional benefits, agronomic advantages, socio-economic opportunities, agricultural and environmental sustainability of the ULs. Several literatures highlighted that ULs have anti-nutritional properties such as tannins, oxylates and phytic acid, and are susceptible to pests and diseases.

Climate change has impacts in crop diversity and vulnerability to new diseases and pests. Imperatively, the cultivation and utilization of ULs can overcome a multifaceted stresses, and have a significant potential to enhance food security and sustainability in small-scale farming communities across developing countries. ULs provide essential nutrients and improving soil fertility through nitrogen fixation to diversifying income streams and supporting biodiversity; likely, they can play a crucial role in bolstering agricultural resilience and livelihoods. Moreover, their genetic diversity offers opportunities for initiative and further breeding programs aimed at developing more resilient crop varieties capable of withstanding environmental stresses. By promoting and integrating ULs into local farming systems, it supports local initiatives, policymakers and stakeholders, hence, foster inclusive growth, empower local communities, and ensure long-term food security amidst global challenges. Embracing these legumes not only safeguards cultural heritage and traditional knowledge but also paves the way towards the global sustainable development goals, contributing to a more resilient and equitable food system for future generations. Generally, the promotion and cultivation of ULs enhance agricultural sustainability, resilience, and economic stability for small-scale farming communities.

To enhance food security and climate resilience, a strategic and multi-pronged approach is essential for promoting ULs. Governments, research institutions, agriculture higher educations, and agricultural stakeholders should prioritize policy support, investment in research, and farmer education to integrate the ULs into local and national food systems. Specifically, mobilizing breeding programs via leveraging genetic diversity should focus on improving yield, pest and disease resistance, and climate adaptability, while seed banks and participatory breeding initiatives must be strengthened to conserve valuable traits.

Additionally, capacity building in targeted extension services, farmer training programs, and financial incentives should be implemented to encourage adoption and ensure sustainable cultivation of the ULs. Strengthening market linkages, agro-food processing infrastructures, and consumer awareness campaigns will further enhance the economic viability of these legumes. Likely, public-private partnerships can play a key role in scaling up production, value addition, and commercialization efforts. Ultimately, to fully harness the potential of ULs in small-scale farming communities, a coordinated effort among researchers, policymakers, stakeholders, entrepreneurs, and farmers is crucial. By fostering innovation technologies such as plant phenomics and breeding, value add chain, and climate smart agriculture practices would support the sustainability of these crops. This can significantly contribute to long-term food and nutrition security, environmental sustainability, and economic empowerment of the small-scale farming communities in developing countries.

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