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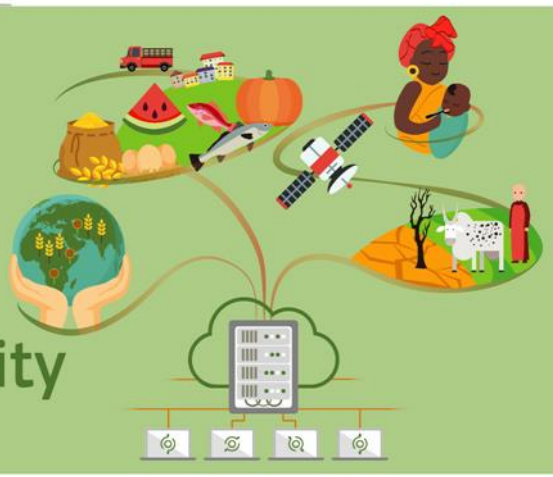

Neglected and Underutilised Species (NUS): Potential for Food and Nutrition Security – a Knowledge Review

2025

HIGHLIGHTS

- Global food systems are currently dominated by only three crop species (rice, wheat and maize) providing half of the world's plant-derived calories. While this brought remarkable productivity gains, it has also made food systems more vulnerable.

- Neglected and Underutilised Species (NUS) are an essential part of agricultural systems in the global south and of daily eating habits for many rural communities. However, several drivers led to their neglect and underutilisation

- NUS can contribute to food security by increasing food availability during the lean period, improving production under harsh conditions and on marginal soils; enabling communities to engage in diversified income-generating activities; buffering seasonal, social and climate driven variability; the early maturation and shorter growth cycle of some NUS also contribute to food security.

- Many NUS are rich in essential macro and micronutrients. Several NUS have also antioxidants and anti-inflammatory properties and deliver other health benefits.

- Many NUS exhibit higher tolerance to stresses such as drought, pests, and diseases compared to mainstream crops. Several NUS can thrive in poor soil conditions. They can thus play an important role in making food systems more resilient to climate change.

- NUS are well suited for environmentally friendly farming practices and agroecological approaches, such as crop rotation, intercropping, green manuring, and agroforestry systems. These contribute to soil health and can bring other environmental and climate benefits.

- Women play a central role in preserving, cultivating, and marketing of NUS. They act as custodians of traditional knowledge, seed systems and are innovators in the kitchen. Promoting NUS can contribute to women's empowerment.

- NUS are largely produced and sold by smallholder farmers in informal markets; hence, their availability to consumers is often limited to the region where they are grown, and only when they are in season The high market value of certain NUS presents an opportunity for rural communities to generate income. However, this is hindered by the underdevelopment of value chains and processing methods.

- Investments in adequate seed systems (in-situ and ex-situ) and inclusion in extension services are needed to make seeds and knowledge available and to scale the uptake.

- There are still big knowledge and research gaps on the agronomic traits, nutritional value, breeding, production, processing technologies and market potential of NUS. Investment in Research and Development is crucial to address these gaps.

- NUS should be mainstreamed into food/agricultural policies, plans and programmes, adopting a holistic approach that considers simultaneously nutrition, income generation and environmental/climate benefits.

- NUS can play a role in emergency situations as alternative ingredients for locally-produced, cost-effective Ready-to-use therapeutic and supplement foods (RUTF-RUSF). Building on promising experiences, additional research is needed on this.

- NUS value chains should be developed, through capacity building, training, improved storage and packaging, improved transportation, targeted investments in rural infrastructure and investing in processes with added value.

1. INTRODUCTION: DEFINITIONS AND INTEREST

Of the thousands of edible plant species estimated to exist worldwide, global food systems are currently dominated by only three crop species: rice, wheat and maize. These provide more than 50% of the world's daily requirements of calories and protein and cover around 40% of global arable land [1]. Nearly 80%–90% of human total dietary intake comes from just 12–20 species [2]. While the focus on high yielding crops has driven remarkable productivity gains, it has not always translated into improved food security or nutrition outcomes. Instead, it has increased the vulnerability to a variety of shocks, including climate change effects and extreme weather events. It also contributed to the erosion of agro-biodiversity and exacerbated the risks of crop failures, ultimately reducing the resilience of food systems.

Against this background, Neglected and Underutilised Species (NUS) have gained attention as a viable option to address the above-mentioned challenges and foster the transition to more sustainable food systems [2, 3, 4, 5, 6].

This knowledge review synthesises evidence on NUS in the following areas:

- NUS's contribution to food security
- Nutritional benefit of NUS
- Consumer preferences and consumption patters
- The role of women in production, use and conservation of NUS
- Economic benefits of NUS
- Environmental and climate benefits of NUS Production of ready-to-use therapeutic or supplementary food (RUTF or RUSF).
- International initiatives supporting NUS

It is based on 64 sources including technical reports, scientific papers and books, with a geographic focus on Africa. Several of the examined papers are literature review, each, in turn, based on many individual studies.

Different terminologies are found in literature (Box 1). For the sake of simplicity, the term NUS will be used in this Knowledge Review as it is the prevailing designation in the literature.

Box 1. *Different terminology used*

There are different names in the literature related to neglected and underutilised species (NUS). Although they have a slightly different focus, they are often used interchangeably [1, 7]: indigenous and traditional food crops [1, 5, 7], orphan crops [2, 5, 7, 8, 9], forgotten foods/crops [2, 5, 7, 10, 11], minor crops [5, 7, 12, 13, 14], under-used/under-exploited crops [1, 15], under-developed crops [1, 8, 15] promising crops [1, 7, 15], lost crops [1, 7, 16], alternative crops/food [1, 15, 17] traditional food crops [1, 4, 7], niche crops [1, 8, 15], future smart food [1, 7, 15, 18], opportunity crops [6]. In the humanitarian context, especially regarding the formulation of Ready to use therapeutic or supplement food (RUTF/RUSF), the term NUS is rarely used, while literature mainly refers to local crops [19, 20, see section 8].

The term NUS was developed by IPGRI in 1999 [15] and **refers to plant species left at the margins of research and development, policy makers and markets** [21]. NUS include wild, semi- or fully domesticated plants from different food groups: cereals, vegetables, legumes, roots and tubers, fruits, trees, oilseeds, nuts, and with life cycles (annual, biennial, perennial) [7] (Table 1). Other definitions also include livestock, mushrooms, algae and other marine products; this knowledge review covers plant species.

It is also acknowledged that concepts are not always understood in the same way in the literature. The terms 'indigenous', 'traditional' and 'local' emphasise the occurrence in a local and cultural context. The term NUS refers also to plants that are traditionally grown for local sustenance in their regions of origin and are adapted to specific agro-ecological conditions. However, NUS comprises a wide range of species, from less known wild fruits to well-established crops like sorghum, millet and cassava, used as staple food in many countries, and processed, marketed nationally and traded across borders. Accordingly, the economic contribution of NUS varies across species: from importance for the household level up to major staple food in a region. The common

feature is that, despite their importance, they received in the past little attention from research and conservation efforts and were therefore generally considered as less competitive. The term NUS is also used in the literature to describe *neglected varieties of mainstream crops*, which, despite their potential, are overlooked. In this review, we refer to NUS mostly related to *species.*

***Table 1**. Examples of NUS from examined literature – common and scientific names*

Cereals and pseudocereals	Pearl millet (*Pennisetum glaucum*), small millets such as finger millet (*Eleusine coracana*), foxtail millet (*Setaria italica*) and barnyard millet (*Echinochloa crusgalli and E. colona*), fonio (*Digitaria exilis*), sorghum (*Sorghum bicolor*), teff (*Eragrostis tef*), African rice (*Oryza glaberrima*), amaranth (*Amaranthus* spp.), quinoa *(Chenopodium quinoa)*
Roots and tubers	Yams (*Dioscorea* spp.), cassava (*Manihot esculenta*), taro (*Colocasia esculenta*), sweet potato (*Ipomoea batatas*)
Legumes	Cowpea (*Vigna unguiculata*), pigeon pea (*Cajanus cajan*), Bambara groundnut (*Vigna subterranean*), mung bean (*Vigna radiata*), Kersting's groundnut (*Macrotyloma geocarpum*), Lablab bean (*Lablab purpureus*), jack bean (*Canavalia ensiformis*)
Vegetables	Leafy vegetables: leaves from amaranth, pumpkin (*Cucurbita pepo*), cassava and bitter leaves (*Vernonia* spp.), spider plant (*Cleome gynandra*), African/ black nightshade *(Solanum scabrum/ nigrum)*, okra (*Abelmoschus esculentus*); eggplants (*Solanum aethiopicum, Solanum macrocarpon*)
Tree products, fruits and other	Marula (*Sclerocarya birrea*), baobab (*Adansonia digitata*) fruit and leaves, tamarind (*Tamarindus indica*), enset (*Ensete ventricosum*), moringa (*Moringa oleifera, Moringa stenopetala*)

Source: [11]

Many drivers led to NUS neglect and underutilisation and limit their wider adoption. These include loss of knowledge, lack of market infrastructures, insufficient research, lower yields compared to major crops, inadequate policies, and others, as summarised in Table 2.

***Table 2**. Drivers to the neglect and underutilization of NUS*

Social	Farmers preferences for new varieties and improved crops
	Changes in diet that accompany urbanization and the growing middle class
	Loss of the indigenous knowledge of NUS
	Inadequate awareness of the nutritional value of NUS
	Low consumer preference due to taste, cooking requirement or perceived low status
	Overexploitation of wild resources
Economic	Changes in land use
	Lack of competitiveness of NUS with other crops
	Lack of market infrastructure
	Lack of processing techniques
	Lack of market niches for NUS and value chain development
	Lack of incentives for farmers to continue to maintain NUS in their fields and gardens
Environmental	Genetic erosion of NUS gene pools
	effects of climate change, degradation and pollution
Agronomic	Insufficient knowledge on production, propagation materials and seeds
	Ill-defined seed systems
	Insufficiently trained human resources
	Low yield performance of many NUS
Political	Failure of national and local governments to make conservation and use of NUS a priority
	Insufficient ex situ conservation (including funding and facilities)
	Lack of relevant traditional information, genetic and phenotypic data on NUS
	Insufficient scientific research on NUS
	Lack of characterization, breeding and evaluation information
	Absence of legal frameworks, policies, projects, national programmes and strategies that promote NUS
	Lack of integration between conservation and use programmes

Source: [5, 14]

2. NUS CONTRIBUTION TO FOOD SECURITY

NUS are an essential part of daily eating habits for rural communities in many countries around the world [2]. A scientific review analysing 75 articles found substantial evidence that NUS contribute directly towards food security (82% of the reviewed literature). They do so by enabling communities to engage in activities that improve their livelihoods and local agricultural systems; contributing to food availability, food access and food systems' stability; improving production and productivity, particularly under harsh conditions; and by acting as "natural insurance" for food security in times of adversity [5]. Similarly, a qualitative review based on 134 papers concluded that in areas where food availability is still limited, NUS can boost local diets and lessen the monotonous reliance on agricultural items [4]. Higher adaptability of NUS to unfavourable conditions and difficult soils is recurrently mentioned as a key NUS feature contributing to food security [4, 6, 14].

For example, in Niger and Mali, traditional varieties of sorghum and pearl millet played an important role in the survival strategies of poor farmers over the 20-year period of drought (from the mid-1980s) thanks to their higher adaptability [14]. In home gardens of East Java, root crops (taro, yams, cassava) were found to buffer food supply chain during climatic adversity [22]. A study from Peru, Myanmar, Vietnam and Zimbabwe, showed that NUS helped indigenous peoples and smallholder farmers in coping with the so-called hunger period, when the previous year's food stores are depleted, and the next harvest is not yet available [13].

In South-West Ethiopia, the indigenous banana enset, also known as the 'false banana', provides the starch staple for 20 million people. It also provides fibres, medicines, animal fodder, roofing and packaging. Its characteristics enable subsistence farmers to harvest as required throughout the year, buffering seasonal, social

and climate driven variability [23, 24]. Thanks to these traits, enset-growing communities reported little-to-no food insecurity during the devastating famines of the 1980s [24] (see also section 7).

Early maturation and shorter growth cycle of some NUS compared to mainstream crop is another feature that can contribute to food security. Small grain millets (e.g. finger and foxtail millet) mature fast, in 60–70 days, yet provide reasonable and assured harvests. In particular, the grains of barnyard millet (*Echinochloa colona*) can reach maturity just 45 days after sowing [7]. Fonio is also known to be a fast-growing crop, producing grains earlier than most mainstream crops [6]. A subset of NUS is made by African Leafy Vegetables (ALV), comprising all plants traditionally grown in Africa whose leaves, fruits or roots are acceptable for use as vegetables [25]. Several ALV also grow quickly and can be harvested within a short time, which could make them valuable for nutrition-intervention programs [25]. Amaranth for example is ready for harvesting between 20 to 45 days after transplanting or sowing [26]. ALV can also contribute to maximising the productivity of small parcels by using spatial and temporal niches in the farming system [25].

Currently, NUS do not receive much attention from public policies and investments. The agricultural policies are often biased towards commercial crops (e.g., maize, rice, and wheat), with little to no focus on their local traditional alternatives [6]. African governments invest more in crops with higher production potential and market demand to address persistent food insecurity [6]. Evidence from West Africa suggests that current policy and governance frameworks are not supportive or can, even, hinder the development of NUS [16]. For example, input subsidies (e.g., for fertilizer and improved seeds) for commercial crops in West Africa have been documented to divert traditional crop farmers from producing NUS [16].

There is a high consensus in the literature regarding the recommendation to **mainstream NUS into food related policies.** The approach to promote NUS should be holistic, interdisciplinary, multi-sectoral, highly participatory and gender sensitive [7]. Coordinated, multisectoral policies need to be developed that recognize the importance of NUS, and integrate explicit in the objectives the link between biodiversity for food and nutrition security [3, 16]. Further, the integration of strategies for NUS conservation and use into national agricultural policies, the promotion of equitable benefit sharing arrangements, and the support to producers and value chain development is needed [15, 21]. Some authors argue that the promotion of NUS could also contribute to food sovereignty and food import substitution [16]. Further research is needed to understand the role of policy and governance in the mainstreaming of NUS and their integration into food systems and diets [16]. Furthermore, monitoring and evaluation mechanisms should be put in place to track progress, e.g. in NUS conservation and use, assess the impact of interventions, and identify areas for improvement needs to be established [21].

Literature recommends including **NUS in the design of projects** that target nutrition, improved incomes or agricultural resilience. The projects should be carried out in a highly participatory fashion, involving all stakeholders and giving ample space to women and traditional knowledge holders, especially for the selection of species and the development of the value chains [1, 7, 16].

3. NUTRITIONAL BENEFITS OF NUS

NUS are rich in essential nutrients -proteins, carbohydrates, fats - and micronutrients like vitamins, calcium, zinc, and iron, which are vital for maintaining good health and preventing diet-related health problems [3, 4, 6]. A large body of evidence indicates that NUS can offer a viable solution to improving dietary diversity and addressing nutritional deficiencies complementing staple foods [3, 5, 6, 14, 25].

Examples of nutrient-rich NUS include moringa, amaranth, millet, cowpea, Bambara groundnut, and several ALV such as leaves of cowpea, cocoyam, sweet potatoes, and cassava, which are rich in iron, zinc, calcium, and dietary fibre. Table 3 shows the nutrient content of some NUS compared to mainstream crops of the same group.

Evidence from case studies in 8 countries (Brazil, Kenya, Guatemala, India, Mali, Sri Lanka and Turkey) shows the nutritional value (macro- and micronutrients, as well as beneficial bioactive non-nutrients) of 188 NUS crops and wild edibles species which can contribute to dietary health and play a key role in addressing local challenges linked to malnutrition, climate change, poverty and shrinking food biodiversity [3].

A study in Kenya found that adding wild NUS to the diet lowered costs and helped meet micro-nutrient requirements, especially for iron, in women and children aged 1-2 years, concluding that without them, poor households would hardly have been able to afford a nutritionally balanced diet [14]. Pharmacological studies and ethno-botanical analysis on various NUS demonstrate their pharmacological activities and contribution to

people's health [27]. NUS tend to have lower glycaemic indices [12] and contain bioactive compounds that support overall health and disease prevention [5, 12, 27].

***Table 3**. Nutritional values of NUS and comparison mainstream crop (darker grey cell) of the same group*

NUS Groups	NUS and comparable crop	Iron (mg/100g)	Protein g/100g	Calcium (mg/100g)	Zinc (mg/100g)	Vitamins (A, Folate/B9, C)
Vegetables	Malabar spinach (*Basella alba*)	10.9	3.4	116.5	0.5	Vit. A (229µg), Vit. C (53.95 mg), Folate (127µg)
	Spinach (*Spinacea oleracea*)	2.81	3.05	125.4	0.61	Vit. A (518µg), Vit. C (13.5 mg)
	Shona cabbage *(Cleome gynandra)*	1.46	2.58	160	0.47	Vit. A (119 µg) Vit. C (15 mg)
	Cabbage (*Brassica oleracea*)	1.40	3.38	42	0.42	Vit. A (38 µg), Vit. C (85 mg)
Cereals	Teff (*Eragrostis tef*)	150	13.3	180	3.63	Vit. A (1 µg)
	White Fonio *(Digitaria exilis)*	29.4	7.1	40	2.79	Folate (120 µg)
	White rice (*Oryza sativa* L.)	0.39	3.2	5	0.68	Lack vitamins A and C
Roots and tubers	Orange-fleshed sweet potato *(Ipomoea batatas)*	0.9	1	54	0.62	Vit. A (791 µg) Vit. C (31mg)
	Irish potato (*Solanum tuberosum)*	1	1.5	6	0.37	Vit. A (0) Vit. C (14 mg)
Legumes	Chickpea *(Cicer arietinum)*	6.8	22.3	235	3.37	Vit A. (15 µg) Folate (400 µg)
	Kidney bean *(Phaseolus vulgaris)*	6.4	20.5	106	2.78	Vit A. (1 µg) Folate (272 µg)
Fruits/ tree products	Marula fruit *(Sclerocarya birrea)*	3.4	0.70	35	0.31	n.a.
	Apple *(Malus domestica)*	0.12	0.26	6	0.04	Vit. A (3 µg) Vit. C (4.6 mg)
Daily nutritional requirements [41]	**Children 1-3 y**	7 mg	13 mg	700 mg	3 mg	Vit A 300 µg Vit C 15 mg Folate 150 µg
	Pregnant and lactating women	27 mg	71 mg	1.300 mg	13 mg	Vit A 1.300 µg Vit C 120 mg Folate 600 µg

Source: JRC, based on [6, 11, 15, 25, 28, 29, 30, 31]

Antioxidant and anti-inflammatory properties have been reported for several NUS, including amaranth [5, 12], millets [7], Bambara groundnut [27], marula [28], Ethiopian Chaya (*Cnidoscolus chayamansa*) [4], moringa [32] and baobab [6]. In the Democratic Republic of the Congo, NUS are used to cure a variety of diseases, among which hypertension, ascariasis, flu, hernia, intestine worms, prostate diseases, inflammations, urinary complications, cutaneous diseases, poison/food intoxication, intestine troubles, and liver disease [12].

Crops like rooibos and moringa have gained international acclaim for their therapeutic potentials in targeting many diseases, like diabetes, cardiovascular diseases, including hepato- and nephro-protective activities [27]. Moringa in particular can be used to treat a variety of disease, including hypercholesterolemia, hyperthyroidism, and to prevent anaemia [32, 33]; extracts from seeds are used as analgesic and for skin and hair care [32]. Kersting's groundnut reduces the occurrence of atherosclerosis and coronary heart disease, as it has a low fat and sodium content [34]. Furthermore, many cereal NUS - teff, fonio, millets - are gluten-free, making them suitable options for celiac people [6], and attractive for urban and global markets (see also **Box 2**).

NUS can play an important role also in contributing to biofortification (breeding crops to be more nutritious) [9]. The combination of diversification and biofortification can support nutritional improvements [9].

It has to be acknowledged that the extensively studied relationship between crop diversity, dietary diversity, nutrition, and health is complex, and results are sometimes conflicting. For example, some NUS contain anti-nutritional factors, i.e. chemicals that interfere with the digestion, absorption, and utilization of nutrients [6, 7]. When consumed in large amounts, these substances can negatively impact health, examples being Lima bean (*Phaseolus lunatus*), fonio, and Bambara groundnut [6].

Schools may serve as both institutional markets for NUS and platforms for improving nutrition through education and behavioural changes, in combination with other strategies [3]. As an example, in Guatemala, ministries and local NGOs integrated NUS into school meal programs. The National School Feeding Law approved in 2017 emphasizes procuring fresh foods within the vicinity of the school, preferably from local producers who practice family farming. Inter alia, the nutrient-rich leafy vegetable chaya (*Cnidoscolus aconitifolius*) was introduced in two school menus, benefiting over 80 500 students. Furthermore, the local vegetables chipilín (*Crotalaria longirostrata*) and black nightshades (*Solanum americanum/ nigrescens*) were also proposed for inclusion [3].

The examined literature recommends that knowledge and research gaps should be addressed to provide more **evidence on nutritional value** (including pathogenicity) of NUS [4, 5, 6, 7, 12, 34]. To this end, establishing a **data base with metrics and indicators** to define the values of NUS in terms of nutritional and medicinal values would be beneficial [2]. Furthermore, future research programmes should prioritise the **breeding of NUS, including biofortification** [4, 9], as well as **clinical trials to investigate their health impacts** [4].

Box 2. Millets

Millets are a group of diverse small-grained cereals adapted to drylands and changing climates. They include various grass species that produce small grains such as pearl, proso, foxtail, barnyard, little, kodo, browntop, finger and guinea millets, as well as black and white fonio, sorghum, teff and Job's tears. Millets have been cultivated and eaten for millennia and are now primarily consumed in sub-Saharan Africa and South Asia, however, harvested area and production is lagging behind compared to rice, wheat and maize. From 1961 to 2023, the share of millet over the sum of these 3 crops has declined from 10.2% to 5.2% in term of harvested area and from 4% to 1% in term of production. The annual global production as of 2023 was around 31.6 million tonnes versus 2 840 million tons for wheat, maize, and rice aggregated [own elaboration from 35]. Compared to these three crops, millet is richer in dietary fibres, iron and other micronutrients while having equal or greater energy content; it is gluten-free and can grow in poorer soils and under harsher conditions [6]. It thereby presents substantial opportunities for food and nutrition security [30].

The International Year of Millets 2023 was promoting millets and sorghum, and the FAO is further fostering them in their "One Country One Priority Product Initiative" [21]. Some challenges that need to be addressed regard mechanisation, as the small size for millet grains make them more difficult to process. For instance, fonio millets are predominantly harvested using sickles and processed using mortar and pestle. The traditional threshing and dehusking require tedious washing of the grain in water to remove the residual sand. There has been progress in manufacturing time-saving and quality-enhancing processing machines, but their prices remain restrictive and ownership is almost exclusively achieved through collective acquisition by farmer groups or downstream organizations [6].

4. CONSUMER PREFERENCES AND CONSUMPTION PATTERNS

Consumption patterns of NUS vary across regions, seasons, local traditions, socio-economic status, and consumer awareness [6, 9, 17]. NUS encompass a diverse array of food crops, each facing unique consumption patterns. A common characteristic of many NUS is that their consumption is declining or lagging behind that of comparable improved varieties, but they also bear the potential to enhance local cuisine by adding flavour and revive gastronomic traditions [3].

In many regions of Africa, NUS are an integral part of local culture and identity, widely used in traditional food preparations, associated with social and religious ceremonies, and increasingly in the spotlight of efforts for revitalizing local food cultures, and to celebrate the identity of the 'terroir' [1]. For example, in East

Nigeria, the "new yam" festival, rooted in Igbo agrarian culture, marks the harvest and fosters community gatherings [27].

A semi-structured questionnaire administered to 40 agricultural stakeholders from 16 African countries by the Forum for Agricultural Research in Africa found that the main reasons for NUS underutilisation (both from production and consumption side) are the lack of knowledge of the nutritional potential, followed by lack of availability due to biodiversity loss, negative image, few recipes, intensive labour requirements, presence of anti-nutritional factors, and low sensory palatability [31. Other studies also showed that barriers for NUS integration in diets are limited and fragmented knowledge on their nutritional value and potential benefits; poorly developed markets and infrastructure, low consumer awareness, and negative perceptions associated with their consumption [3].

Most consumers are inadequately informed about what constitutes a balanced diet; they do not necessarily prioritize nutrition and health when choosing food [3]. Even when fruits and vegetables are available, accessible, and affordable, people often do not consume diverse varieties in sufficient quantities. This may be due to desirability factors beyond cost and availability, including perceptions, habits, time, preferences, seasonality, and food safety [6].

The social perceptions, particularly in urban contexts, is sometimes low. NUS are occasionally associated with negative connotations which affects their consumption. Some food from NUS are stigmatized as "poor man's food", are seen as "animal feed" or "famine food" [1, 4, 5, 36]. Specific examples from literature include millet in India, ALV in Kenya [1], or stinging nettle (*Urtica simensis*) in Ethiopia [4] and many wild NUS. Sometimes NUS are associated with illness—as many of the species have medicinal properties—thus evoking negative experiences and perceptions [3]. For example, in Zimbabwe, the nutritious NUS Tsine (black jack) is stigmatized as food associated with HIV patients, discouraging others from eating them [13].

Younger generations sometimes show reluctance to learn about NUS and associate negative attitudes towards them, considering them as old fashioned [27]. In Nairobi in Kenya a study has shown a strong correlation of consumer attitudes and age. While the acceptance of NUS was generally high, the consumption of NUS in the younger generation was decreasing. Marketing practitioners and policy-makers need to understand the perception of potential NUS consumers [27].

Consumers might refrain from eating specific NUS requiring more time for preparation. Some NUS are in fact difficult to dehusk, thresh, or take hours to prepare, making them less attractive [27]. For example, in Cameroon, bitter leaf needs to be washed several times and cooked with potash to remove the bitterness [25]. False sesame (*Ceratotheca sesamoides*) requires additional preparations to become more palatable and avoid laxative effects [34]. Further, some NUS require the removal of their anti-nutritional factors before consumption. A case study in Hoima region, Uganda, reports that farmers consume frequently those NUS that are tasty (yam, groundnuts), high yielding (sorghum), or associated with health benefits (amaranth). They rarely consume those that are less palatable and harder to prepare (black nightshade), or less accessible like wild fruits [10].

Because of all these factors, over time, NUS's cultivation and consumption have decreased, although they remain an essential part of daily eating habits for many poor rural communities in many countries around the world [2].

Raising urban and global demand can support the production of NUS. This can be achieved by promoting their health benefits or incorporating them into modern lifestyles. However, making NUS attractive to wealthier households can be challenging and takes time. Integrating NUS into retail products has proven to be an effective strategy. In India, the promotion of finger millet gained momentum when it was included in the recipes of savoury snacks like momos and samosas, and was featured in food blogs, cooking shows, and restaurants [1]. Similarly, in Kenya, the demand for ALV increased when a few supermarket chains, popular among higher-end consumers, began stocking them [1]. Growing attention will open up new markets with big opportunities, as described in the literature for teff and quinoa. As for their nutritional value they are seen as "superfood" and conquered the diets of urban populations in the US, Europe, and Asia, which led to a global production boom [6, 29]. Fonio is also gaining traction in health-conscious markets, presenting significant opportunities for farmers in regions like West Africa and Ethiopia [1, 3, 6, 12].

It is vital to equip stakeholders with knowledge regarding the appropriate use and value of NUS for their nutritional, health, medicinal, cultural and environmental benefits [2]. Effective dissemination of information should present products that appear appealing and delicious [7] and show their nutritional benefits [3, 4, 27]. Social

behavioural change strategies should also target cultural norms and preferences [6], e.g. by distribution of attractive recipes, engaging chefs, food movements, school education, and food festivals [1, 7, 15].

Food policies should aim to improve the quality of the food environment, for instance, through social marketing programmes, food labelling, food price policies, and nutrition guidelines [15]. To further support the promotion of NUS, public procurement mechanisms favouring the supply of NUS from family farmers and collectors should be implemented, for example by also including them in school feeding programs [3, 7, 15].

5. THE ROLE OF WOMEN IN PRODUCTION, USE AND CONSERVATION OF NUS

Women hold a pivotal role in the conservation, cultivation, processing, and preparation of NUS, particularly during periods of food insecurity [7, 12, 13, 34]. They are primary guardians of traditional knowledge and seed systems, essential for preserving and using NUS. However, genetic resources improvement, seed systems, and the broader value chain of NUS - managed, sustained and fuelled within rural communities primarily by women - are currently considered marginal [5].

In many cultures, the division of labour assigns men to staple and commercial crops, while women focus on NUS, especially wild and cultivated vegetables, which are often grown on small marginal plots [12, 14, 34]. For example, in Cameroon, Bambara groundnuts are predominantly grown by women (around 78% of all growers) [6].

Women play a crucial role in producing and marketing ALV, as seen in Kenya [34]. The income generated from ALV significantly contributes to household food security and enhances women's financial independence [25]. These vegetables grow quickly and can be harvested within short period, and women use them to sustain their families and support their health [25]. Similarly, in the South-Kivu province of the Democratic Republic of the Congo, women are the main producers and vendors of ALV, selling amaranth and African nightshade in the form of bundled branches in the markets [12]. Women-led cooperatives have been instrumental in commercializing ALV products, and public-private partnerships have helped integrate them into school feeding programs, encouraging broader use [1].

Promoting NUS can therefore help empower women and increase their income, enhancing their economic autonomy and preserving cultural identity [2, 3, 5, 12, 14, 27, 34]. The positive impact of NUS on women's social position has been observed in Benin, where women's increased income from these crops has led to enhanced social status [27]. An example from Sri Lanka, showed that rural women who were trained by the public Women Farmers' Extension Program and selling their traditional food in 20 food outlets called Hela Bojun (literally, True Sri Lankan Taste) earn between US $600–$800 a month, sufficient to enrol their children in school and support the family household [3].

However, the additional burden sometimes associated with NUS harvesting and processing, mostly carried by women, need to be addressed. Targeted measures can be effective: for example, in India, the introduction of specific machines for minor millet processing lowered considerably the required labour from women. As a result, millet consumption increased and women reported improved social satisfaction, more opportunities to earn extra income, and strengthened independence and financial security [1, 15, see also section 6].

The consulted literature emphasizes the need to **mainstream empowerment of women across NUS promotion strategies**. Gender transformative approaches should address power dynamics and structures to overcome social and cultural barriers and other forms of inequality in the adoption and management of NUS [2]. The selection of species to focus on should be carried out in a highly participatory fashion, involving all stakeholders and giving ample space to women, who are the strategic nexus between biodiversity and nutrition in households [7]. To achieve this, gender-sensitive strategies are essential in addressing production-level barriers [1, 5, 7, 16, 25, 34], and should include interventions tailored to mobility, caregiving roles, local norms, and women's empowerment in value chains [15]. Additional measures such as marketing training, scholarships, and investment programs should be promoted; i.e. also for indigenous communities and youth entrepreneurship [1, 15]. A gendered perspective is recommended for future research that take an in-depth analysis of the potential of NUS to build livelihood capital [34].

6. ECONOMIC BENEFITS OF NUS

Many NUS are largely produced and sold by smallholder farmers in informal markets, which means they are typically available to consumers in the region where they are grown, and only during the time of the year when they are in season [27]. **However, some NUS have considerable market value and economic**

potential; their sales can make a significant contribution to household income and livelihood especially for women and smallholder farmers [4, 5, 6, 12, 14, 26, 27, 28, 34, 37].

Some NUS are already now of major economic importance in different African regions. As for cereals, teff for example is one of the most important crops in Ethiopia in terms of production and consumption, representing the staple food for 60-75% of its population, as well as being an important cash crop [29].

Looking at legumes, cowpea is one of the main crops grown in Nigeria and Niger [38] representing a major source of income for small scale farmers. In Niger, it is the third crop in terms of cultivated area (32% of the total [39]). As of 2022, the cowpea value chain in Niger represented 14.7% of the country's GDP and 13.2% of total value added in the agricultural sector, generating some 168 million EUR in revenues for the state [40]. The World Bank has identified cowpea as key both for food security and as a cash crop, and the one with the highest attractiveness and desirability for agricultural value chains development in Niger [39].

As for tubers, cassava is an important agricultural product in several African countries and the main one in the Democratic Republic of the Congo, where its value chain is considered overall rentable and sustainable, though with significant potential for improvement. It represents around 4.9% of the country's GDP and employs 780 000 people, 60% of which are women [41]. In response to the price surge of wheat flour, a cassava derived flour is increasingly used in the country to make bread [41].

Vegetables like amaranth, edible rape (*Brassica napus, Brassica oleracea*), cassava leaves, garden egg (*Solanum melongena*) and jute mallow (*Corchorus tridens*) are of appreciable commercial value [27]. In Benin, benefits to smallholders' livelihoods were reported for an underused pumpkin (*Cucurbita moschata Duchesne*), due to its multipurpose nature (consumption, therapeutic, and commercial) [4]. In the Democratic Republic of the Congo, 23 NUS species were identified to be used as source of income and for medicine, besides food [12]. A study from Uganda reported that groundnut, yams, sorghum, finger millet, fruits and pigeon peas provided additional sources of income to small scale farmers [10]. Several examples of profitable cultivation of traditional vegetables are reported in East and West Africa, including worowo (*Solanacio biafrae*), cockscomb (*Celosia argentea*), African eggplant, and amaranth [26]. A project supporting amaranth production in Ecuador, led to increased production and sales by 180% and 115% respectively. The annual income of farmers involved in the project rose by 20%. [14]. A project in Morocco supported the domestication of wild fennel, leading to a 75% increase of household's income in just one year [14].

Already now, some NUS are processed for storing and selling. In a few cases, these products have been commercialised nationally and internationally. In Ethiopia, teff is traditionally used to prepare injera, a thin, sour, pancake-like food, which accompanies the majority of the daily meals and it's widely consumed in Ethiopia, Eritrea, Somalia and other African nations and is attracting interests worldwide [29]., such as the marula fruit, which is used to produce the popular beverage "amarula" or sold in local markets in southern Africa [28]. Already in 2007, a study found that some vegetables NUS (e.g. amaranth) were slowly moving out of the underutilised informal market category into the commercial mainstream, becoming an increasingly attractive food group for the wealthier segments of the populace in East Africa and South East Asia (reported by [26, 27]).

Developing harvest and post-harvest technologies is crucial for adding value to raw crops through processing (e.g., drying, grinding, threshing, dehulling, milling, chipping, grating, pressing, and cooking), sorting, packaging, storage, and final distribution through various market channels [6]. **Value Chain Development for NUS may involve high risks** when creating new products with generally scarce previous market experience, low knowledge of consumer needs and targeting new markets [1]. Consequently, it is often difficult to involve private companies, and they often require greater support when exploring new products. However, competition is often less pronounced for NUS value chains compared with established commodity crops. Producer organisations can develop more control and influence in domestic market [1].

The integration in international markets can also have unintended consequences, as shown on the examples of quinoa [6, 29]. Increased market demand and marketing of quinoa resulted in farmers benefiting from higher producer prices and an intensified production. But, while Peru and Bolivia remained the two main producers of quinoa, many other countries in North America, Europe, Asia, and Africa have also expanded their quinoa production. Large, market-oriented producers entered the volatile markets, by reducing labour costs and achieve higher yields which led to a steep decline in producer prices. The teff boom had also negative domestic repercussions in Ethiopia due to increased prices for domestic consumers, which in 2006 led the government to ban export from 2006 to 2015 [6, 29].

On the other hand, **several examples of successful stories of NUS value-chain developments in poor contexts have been reported by the literature** [6, 7, 14, 37]. In Kenya, farmers developed a new type of flour made from cassava, sorghum, and yellow maize (*Zea mays*), which can be used to make porridge for adults and young children at schools, hospitals, and homesteads [37]. A community-led intervention in the same country added value to local cereals NUS (sorghum, finger millets) and legumes through the production and marketing of "pressure popped" snacks [7].

In India, local entrepreneurs produced novel and nutritious millet products, earning net incomes of USD 300 - 950 per tonne. Interventions carried out in different Indian states supported by various national and international agencies demonstrated a wide array of socio-economic benefits from community-centred value chain development of millets. Examples of such activities included the collection, characterization and evaluation of landraces; multiplication of high-quality seeds; revitalization of seed storage and exchange systems through community seed banks and dissemination of best cultivation practices [14].

In Cameroon, a government project implemented between 2014 and 2021 and co-financed by the World Bank supported the development of value chains for cassava, maize and sorghum. According to the project's final report, cassava yields increased from 8 to 22.35 tons per ha; sorghum yields from 1 to 1.91 tons per hectare among beneficiary farmers. Interventions that reportedly contributed to these gains include the rehabilitation of 217 km of roads, the establishment of 115 post-harvest and processing facilities, and the delivery of labour-saving machinery to 8 735 women, and the distribution of seed. The commercialisation of these crops also increased significantly, supporting some 176 000 individuals [6].

NUS untapped status presents prospects for job creation, especially in communities with traditional knowledge of wild crops [28]. The above-mentioned project on minor millet in India for example also created new jobs, especially for women, at the rate of 140 – 300 person-days per tonne of grain produced [14].

Key recommendations from examined literature stress the importance of **efficient storage, processing and packaging techniques** [6, 14, 15, 16, 17]. To deal with the competitive pressure from commercial crop alternatives, it is crucial to enhance modern **value-addition technologies** for NUS. This will require improvements in **infrastructure and a supportive enabling environment**, which is currently lacking and constraining the market economic viability of NUS [6]. The private sector and community initiatives that build up **processing capacities** should be encouraged [6]. Technological advancement is a prerequisite to reduce waste and elevate shelf life while maintaining the nutritional value of processed NUS [4, 7]. **Improved transportation, and targeted investments in rural infrastructure** are key [6].

The development of **alternative retail structures** [2], **digital solutions** and **training on marketing**. (e.g. for indigenous youth) can help improve the market access and scaling up [15]. NUS provide an opportunity to re-engage youth through innovation and agribusiness, using marketing tools though internet, social media, and direct-to-consumer models [15]. Expansion on international markets (e.g. to health-conscious consumers) can create opportunities but also threats. The experiences of scaling of quinoa and teff and the impact on small holders need to be better understood and utilised [6, 29].

Further, it is important to **build capacity** in government, producer, and communities to enable sustainable harvesting, equitable trade, management and processing of wild and forest foods, to increase benefits for local groups [42]. The integration in related **training programs and outreach-efforts of advisory and extension services** [6, 15], and **the access to finance**, can promote the production and processing capacities of small holders [6].

In order to fully realize the potential of NUS, the literature recommends to address **knowledge and research gaps** by collecting and disseminating reliable NUS-related data to support evidence based decisions for policy making and business [4, 6, 12]. Research is needed on the agronomic traits, the market potential of NUS [4, 5, 6, 7, 12, 34] and their use for producing local RUTF/RUSF [20].

7. ENVIRONMENTAL AND CLIMATE BENEFITS OF NUS

The agroecological potential of NUS to contribute to sustainable farming has been documented in several systematic reviews [4, 5, 6, 34, 36, 43]. Compared to mainstream crops, NUS exhibit higher resistance to stresses, in particular drought and heat; lower water requirements; ability to thrive in harsher conditions and poor soils; resistance to pests and diseases; they are also well-suited for farming practices beneficial to the environment, particularly soil (Table 4). Below, each aspect is addressed in more detail.

Resistance to drought and heat stress

Several NUS are more drought-resistant or drought-tolerant than mainstream crops. Among cereals, sorghum and various millets (e.g., finger millet, pearl millet, and barnyard millet) endure drought and other extreme weather conditions also thanks to their deep root systems that also help to stabilize and enhance soil structure, manage soil nutrients, contribute organic matter, and prevent erosion [6, 43]. Minor millet can withstand temperatures up to 48°C [7]. In root vegetables, drought-tolerance is reported for taro and sweet potato [6]. Among leguminous species, Bambara groundnut is regarded one of the most drought-tolerant crops in Africa [6]. Cowpea is also reported to be heat and drought tolerant [38]. Drought-resistance vegetables include the bitter tomato (*Solanum aethiopicum*) and the Ethiopian eggplant (*Solanum macrocarpon*) [4]. Enset (see section 2) is also reported to be relatively drought-tolerant [23, 44].

Low water requirements

Minor millets can produce a reasonable harvest with short rainy seasons (and with about 10% of the water required to grow rice) [7]. Kodo (*Paspalum scrobiculatum*) and Kutki (*Panicum sumatrense*) millets are central elements in the traditional rainfed farming systems in India due to their low water requirements [7]. In South Africa, some NUS showed higher water use efficiency compared to mainstream crops in the same family: among legumes, the common groundnut yields the most but require more water compared to cowpea; among vegetables, sweet potatoes, pumpkin leaves and amaranth showed high efficiency in terms of water consumed per energy and carbohydrates produced [45]. The spider plant is highly efficient in its use of sunlight and water and can thus thrive in hot and arid soils, reducing water loss through its leaves [34].

***Table 4**. Environmental and climate benefits of some NUS in Africa*

NUS groups	Common name	Low water demand	Resilience resp. drought and heat	Stress resistance towards pests and diseases	Adaptation to poor soils	Improvement of soil (fertility, structure and organic matter)	Nitrogen fixation	References
Cereals	Fonio (*Digitaria exilis)*	✓	✓	✓				[3], [6], [11]
	Sorghum (*Sorghum sp.)*		✓					[10], [11]
	Pearl millet (*Pennisetum glaucum)*	✓	✓	✓	✓	✓		[6], [11], [43]
	Teff (*Eragrostis tef)*			✓				[6], [11], [43]
Roots/ tubers	Cassava (*Manihot esculenta)*		✓		✓			[11]
Fruits/ Tree products	Marula (*Sclerocarya birrea)*		✓					[7]
	Wild melon (*Cucumis melo agrestis)*			✓				[34]
	Moringa (*Moringa oleifera*)	✓	✓		✓	✓		[6] , [11], [32], [33]
Legumes	Bambara groundnut (*Vigna subterranean)*	✓	✓		✓	✓	✓	[4], [6], [11], [34]
	Cowpea (*Vigna unguilculata)*	✓	✓				✓	[6], [11], [43]
	Kersting's groundnut (*Macrotyloma geocarpum)*		✓			✓	✓	[34]
Leafy vegetables	Spider plant (*Cleome gynandra)*	✓	✓	✓				[34]
	Amaranth (*Amaranthus dubius)*	✓		✓				[11], [34]

Source: JRC, based on studies reported under the "References" column

Resistance to pests and diseases
Fonio is the least susceptible to pests and diseases among all the millets grown in semi-arid and arid regions [6]. Finger millet can resist well post-harvest pest infestations, and teff is known to be resistant to plant diseases and grain storage pests [6]. Indigenous melon (*Cucumis melo subsp. Agrestis*) is resistant to several pests, including leaf miners, fruit flies, and diseases such as Fusarium wilt, powdery mildew, Zucchini yellow mosaic virus, Cucurbit aphid-borne yellows virus [34]. Moringa is reported to be pest tolerant, though this trait varies across species, with *Moringa oleifera* reported to be more resistant than *Moringa stenopetala* and thus more suited for plantations in southern Ethiopia [33].

Ability to thrive in poor soils
Various underutilised millets (e.g., finger millet, pearl millet, and Barnyard millet) can thrive in poor soils [6]. Fonio grows relatively well in unfavourable terrains, low-nutrient soils, and water-scarce environments; finger millet can also grow in nutrient-poor soils. [6]. Teff thrives in diverse ecological conditions, including areas experiencing moisture stress and waterlogging [6]. NUS that withstand acidic soils and salinity stress include amaranth [6] quinoa, grain amaranth and wild rice [43]. The ALV African nightshade is adapted to a range of agroecological conditions, including poor soils [12].

Contribution to soil health and fertility
Some NUS have traits that contribute positively to maintain or improve soil health. Many underutilised millets have deep rooting systems that help stabilise and enhance soil structure, manage soil nutrients, contribute organic matter, and prevent erosion [6]. Several NUS are nitrogen-fixing crops and can thus be used to enhance soil fertility; notably Bambara groundnuts, Kersting's groundnut and cowpeas [6]. NUS are therefore well suited to be integrated into farming practices like crop rotation, intercropping, or alley cropping, which contribute to soil health through soil coverage, increased organic matter and soil erosion control, nutrient cycling, carbon sequestration, and increased water retention capacity [6, 34, 43].

For example, millets varieties are systematically integrated into crop rotation systems in India [7, 46]. In particular, millet/legumes rotation improves soil fertility; intercropping millets with other crops also leads to better utilisation of soil nutrients and reduces the incidence of pests and diseases [46]. Empirical data from South Africa revealed a significant increase in plant growth, shoot biomass, and grain yield of maize planted after NUS legumes (Bambara groundnut, mung bean and cowpea) relative to maize-maize succession [47].

Moringa is indicated suitable for intercropping with vegetables, fruit trees, and medicinal and aromatic plants and legumes (cowpea, jack bean, lablab and pigeon pea). It's integration in agroforestry systems has been explored in several African countries and can contribute to minimise the negative effects of drought and to rehabilitate and enhance soils in arid zones. Moringa extracts (especially from leaves) and moringa seed cakes are also used as fertiliser, soil amendment or bio stimulant on various crops across Africa [33].

Overall, available evidence enables to conclude that, while NUS have generally a lower productivity compared to mainstream crops, they can be more efficient in marginal environments, and/or in contexts where smallholder farmers use less inputs, especially fertilisers, pesticides and water. While there's a growing body of literature on the environmental and climate benefits of NUS, a significant part of the evidence remains anecdotal and more systematic research and empirical data are needed [34].

The examined literature recommends to **explore and promote the production of NUS in sustainable agricultural practices,** integrating them into existing crop rotation or intercropping practices [7, 17], while focussing on soil health and agro-ecosystems diversity [7, 22].

To **conserve and valorise genetic resources it is essential that** NUS seeds are conserved in-situ (community seed banks) and ex-situ (gene banks) [1, 4, 6, 17, 18]. Additionally, genetic conservation measures should be designed, that also address the risk of over-exploitation when using wild plants [17, 27]. This requires a multifaceted approach, including local taxonomic research to better understand the species in question and a deeper insights on the genomes of ALV [25]. Further, detailed characterizations and assessments of NUS related to their benefits for resilience to climate change, cultural richness and sustainable livelihoods is needed [2].

Furthermore, it is important to **intensify breeding programmes** [4, 6], **develop adequate seed systems and measures for continuous quality seed production and distribution**; and **strengthen and upgrade smallholder seed systems** [2, 5, 6, 12, 16, 22]. To promote sustainable use, it is recommended to engage farmers and grassroots movements in all domestication efforts [1, 21, 27]. Furthermore, research should also

focus on resilience to pests and diseases, modernising production methods, and addressing post-harvest inefficiencies [6].

8. USE OF NUS FOR READY-TO-USE THERAPEUTIC AND SUPPLEMENT FOODS (RUTF/RUSF)

Ready-to-Use Therapeutic Foods (RUTF) and Ready-to-Use Supplement Foods (RUSF) are used in emergency contexts to treat malnutrition. RUTF is an energy-dense food consisting of a homogenous mixture of powdered or dry ingredients, rich in protein and carbohydrates, embedded within the lipid matrix, used to treat severe acute malnutrition. RUSF is a less nutrient-dense food used as a supplement for the management of moderate acute malnutrition [48].

Being used for medical purposes, RUTF production and composition is subject to nutritional and safety/hygienic standards, first proposed by WHO and WFP in 2007; new guidelines have been recently developed by FAO and WHO (2022) [49]. Typical ingredients for standard RUTF are full-fat milk, peanut (groundnut), vegetable oil, sugar, and mineral and vitamin mix [49]. Milk-based RUTFs are considered to be more effective, but milk-free RUSF are cheaper, have a higher shelf life, and can support local agriculture [48]. Additionally, peanuts-based RUTF are not always well accepted in all geographic contexts [50]. Commercial RUTF/RUSF are frequently criticised due to their reputation as imported products made with external ingredients, posing a barrier to their widespread adoption [51]. Therefore, research is ongoing on alternative formulations of RUTF/RUSF based on local products replacing milk and/or peanuts and offering more cost-effective options. Although this branch of literature does not focus specifically on NUS, some of the examined local ingredients belong to this category.

A recent scoping review on the topic identified 53 local RUTF formulations at different stages of development for the treatment of Severe Acute Malnutrition from 42 papers, most of which (25) were from Africa, 16 from Asia, and 3 from other/non-specified areas [52]. A key feature of local RUTF/RUSF is their lower cost [19, 52, 53]. Cost savings ranging from 14% to 52% were reported in the review by [52]. The latter also reported that the effectiveness of locally-produced RUTF in treating malnutrition was no inferior to commercial products in 11 of the 15 available studies of which 6 were from Africa and 5 from Asia.

Another important requirement for RUTF/RUSF is acceptability [19; 52]. Several studies found that locally made RUTF/RUSF are equally accepted by local communities as commercial ones (e.g. studies in Ethiopia, Ghana, and India [54]; Bangladesh [50]; Sri Lanka: [53]) and in some cases even more accepted (e.g. studies from Cambodia [20] and Indonesia [55].

From the examined sources, eleven studies were identified where at least one NUS was used as an ingredient to produce local RUTF/RUSF, 8 from Asia and 3 from Africa. Studied NUS included mung bean, Bambara groundnut, moringa, millet, teff, okra and taro, always used in combination with some mainstream crops, oils, and in some cases, milk.

In Vietnam, a locally produced RUTF containing mung bean was as effective as a commercial product in treating malnutrition and was well-accepted, though slightly less than the latter [56]. In Bangladesh, 2 locally produced RUSF based on rice-lentils and chickpea, respectively, proved to be significantly better compared to the commercial RUSF in terms of overall liking [57].

Research from Ethiopia developed a tool to optimize RUTF formulations and identified 32 possible recipes for alternative RUTF using local ingredients. They proved to be feasible to prepare and met international standards. Four formulations were selected for further analysis and met the specified nutrition requirements; of these, one contained millet and another one teff [58].

In Nigeria, the suitability of a protein-rich extract from okra seeds was tested for its use in RUTF preparation; authors concluded that this is a cheap and safe way of using okra, one of the few crops that grows in every part of the country [59].

In Indonesia, two locally produced RUTF to treat moderately to mildly wasted children were developed. One contained peanuts and milk, the other cereals, nuts and legumes, including mung bean. Children treated with the second RUTF had a higher recovery rate and showed a higher compliance to the treatment [60]. In other study from the same country, a commercial RUSF was compared with 2 local RUSF biscuits made from flour mixes from a local taro and mung bean, mixed with the local banana Nangka (*Musa textilia*) and other mainstream ingredients. Two formulations were selected: taro-peanut and taro-peanut/mung bean. Both resulted in acceptable physical properties, colour, taste, and dimension. However, the recipes' nutritional composition fell short of international standards for preventing malnutrition in children. To address this, a vitamin and mineral

mix was added. The authors conclude that RUSF biscuits should not replace home-based meals but rather serve as nutritious snacks, accompanied by health and nutrition education for caregivers to ensure a balanced diet for children [48].

Two studies in Cambodia tested the effectiveness [51] and acceptability [61] of a local RUTF containing mung bean and a local fish as a protein source to replace milk. No differences were found in the effectiveness of the local RUTF compared to a commercial one [51]. The local RUTF was less accepted by children and caregivers, but was considered equivalent in terms of organoleptic qualities, texture, and ability to swallow. Acceptability increased when the paste was filled in a crispy wafer, making it a more familiar snack [61]. A third study from Cambodia [62] tested the acceptability of a RUSF based on the same ingredients of the RUTF developed in the two previously mentioned studies [51, 61]. The local RUSF was preferred by caregivers, while children preferred the commercial products and ate less local product]. However, the latter had higher energy density, resulting in higher total energy intake.

A study from Pakistan tested shelf-life parameters of several formulations of a locally made RUTF with different proportions of peanut, chickpea, and mung bean. All formulations showed good shelf-life acceptability, and the combination of chickpea and mung bean improved the protein content, the nutritional quality, and textural properties of RUTF. The authors concluded that these RUTF can be used as a replacement for acute, moderate, and severely malnourished infants [63].

In South Africa, 3 RUTF bars were developed using a protein complex and a leaf powder derived from Bambara groundnut. Millet and oats were used as enrichments. The 3 formulations met WHO standards, exhibiting acceptable sensory attributes and nutritional profiles, and low water activity. Authors conclude that RUTF based on local legumes and cereals without milk powder are a viable alternative to commercial RUTF [64].

In summary, the use of local ingredients, including NUS, for the formulation of alternative RUTF/RUSF holds promise in terms of cost-saving, higher acceptability, and potential to contribute to the local economy. However, the evidence on alternative and locally-produced RUTFs is overall still limited, despite the growing body of literature, and further research is needed on the following aspects: i) identification of the best local ingredients, taking into account availability and nutritional properties; ii) the use of milk: a few novel milk-free products were tested with promising results, but more evidence on their effectiveness is required; iii) the assessment of costs should consider all aspects, including cost-effectiveness (e.g., cost per recovered child), rather than only cost per quantity of product; iv) safety, in particular, the occurrence of adverse events, shelf-life, potential of contamination from mycotoxins and aflatoxins [52].

9. INTERNATIONAL INITIATIVES SUPPORTING NUS

AgrEcoNUS+ is a new project funded by the European commission within the DESIRA+ programme to build up sustainable value chains. The project is led by AICS (Italian Agency for Development Cooperation), IFAD, CIHEAM-Bari and SWISSAID. It builds on the previous projects SUSTLIVES and CROPS4HD which aimed to improve the resilience, health and livelihoods of rural communities through sustainable use and conservation of farmers' varieties/landraces, neglected and underutilized species respecting agroecological approaches. It covers 9 African countries: Burkina Faso, Ghana, Guinea, Ivory Coast, Mauritania, Niger, Senegal, Tanzania and Zimbabwe.

The Vision for Adapted Crops and Soils (VACS) is a programme of the global hunger and food security initiative, launched in February 2023 by the US Government with the African Union and FAO. VACS aims to leverage the genetic diversity present in NUS to develop climate-resilient crop varieties and improve soil health. Through research, breeding programmes, and capacity building, VACS seeks to unlock the potential of NUS to address global challenges, such as food insecurity and environmental degradation. This initiative includes the selection of 63 priority crops including several from each of six groups – cereals, roots/tubers, fruits, vegetables, legumes, and nuts/seeds/oilseeds [21]. IFAD has established the **VACS Trust Fund** to direct financing towards investments aligned with VACS priority areas. For instance, projects in Malawi and Côte d'Ivoire, supported by the VACS Trust Fund, focus on sustainable land restoration, the development of resilient seed systems, and market linkages for small-scale producers. The continuation of the program by the U.S. and its partners is currently uncertain.

Power of Diversity Funding Facility (PDFF) is a multi-donor initiative, managed by the Crop Trust, dedicated to conserving, cultivating and promoting the consumption of relatively neglected opportunity crops across Africa, Asia, the Pacific, and Latin America and the Caribbean. Initially, the PDFF focuses on 14 high-potential opportunity crops in seven countries. PDFF is financed by the governments of Germany and Ireland.

BOLD (Biodiversity for Opportunities, Livelihoods, and Development) is a 10-year initiative (2021-2031) funded by the Government of Norway, coordinated by the Crop Trust to protect and utilize crop diversity for food and nutrition security. BOLD is designed to deliver five outcomes that, together will address the key dual challenges of ensuring the conservation of crop diversity in gene banks and making sure crop diversity reaches farmers. One key outcome is the increased use and value of NUCs within agri-food systems in West and East Africa which is being implemented through the project. **BOLDER** (Building Opportunities for Lesser-known Diversity in Edible Resources) is an initiative under the broader BOLD program—aims to conserve underutilised, nutritious crops and make them accessible to smallholder farmers in four African countries: Benin, Ghana, Tanzania, and Uganda. The project has collected detailed information on 15 NUS from these countries in the Opportunity Crops Knowledge Base

Collective Action on Forgotten Foods being led by the Global Forum on Agricultural Research and Innovation (GFAiR) aims to define, together with farmers and other innovation actors, what needs to change for research systems to better support and build on the efforts of local organizations and farmers to take advantage of forgotten foods. The Global Manifesto on Forgotten Foods is the result of a broad and intensive consultation process carried out in Africa, Asia-Pacific, Europe and the Middle East. It was facilitated by a consortium of GFAiR, AARINENA, APAARI, FARA; with support of CFF, and the Bioversity-CIAT. In this process, thousands of actors from many countries took part in research activities, data analysis, presentations and discussions, and in the drafting [2].

African Orphan Crops Consortium (AOCC) aims at the greater integration of NUS into African food systems by sequencing, assembling and annotating the genomes of 101 traditional African food crops, and facilitating their genetic improvement. With teaching based at ICRAF, AOCC also conducts a training program for Africa's plant breeders, to enable them to use advanced breeding methods [6, 9].

FARA has recently published with the FAO the **Compendium on Forgotten Food** and published jointly with GFAIR the **Africa Manifesto and Plan of Action on Forgotten Foods.** Together with Bioversity- International FARA is leading the **Working group on Opportunity Crops in Africa** under the African Seed and Biotechnology Programme of the African Union, starting in September 2025.

One Country One Priority Product Initiative is a five-year programme of FAO launched in September 2021 to promote Special Agricultural Products (SAPs) at global, regional and local levels. These SAPs have unique qualities and special characteristics that can contribute to the transformation to more efficient, inclusive, resilient and sustainable agrifood systems. The products included amaranth (Mexico), jackfruit (Bangladesh), cassava (Central African Republic, Republic of Congo, Democratic Republic of the Congo), sorghum (Somalia, South Sudan), millet (Namibia), quinoa (Bhutan, Bolivia), and teff (Ethiopia). The FAO also raised awareness with the International Year of Pulses (2019), Fruits and Vegetables (2021) and Millets (2023).

Bioversity International – CIAT works on traditional crops within their focus on cassava, beans and bananas. The bananas research, for example, aims to maximize its genetic diversity, develop resilient varieties, and empower banana farmers. For example, to tackle Vitamin A deficiency in East Africa, varieties rich in provitamin A carotenoids can help address the widespread vitamin A deficiency. Some local banana varieties, especially the orange fleshed Karat banana, are particularly rich in this provitamin.

International Institute of Tropical Agriculture (IITA) is addressing staple food crops, including plantain, cassava, cowpea, yam with regards to breeding, plant protection, economic development and nutrition.

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