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KATRIN GLATZEL, CECILIA C. MAINA, AIMABLE NYISHIMIRENTE, JANOSCH KLEMM, MATIN QAIM

Leveraging the opportunities of neglected and underutilized crops for nutrition and climate resilience

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Center for Development Research (ZEF), University of Bonn

Authors’ contacts

Katrin Glatzel
Center for Development Research (ZEF), University of Bonn, and
AKADEMIYA 2063
Email: kglatzel@akademiya2063.org

Cecilia C. Maina
Center for Development Research (ZEF), University of Bonn
Email: s7cemain@uni-bonn.de

Aimable Nyishimirente
Center for Development Research (ZEF), University of Bonn
Email: aimable1998@gmail.com

Janosch Klemm
Center for Development Research (ZEF), University of Bonn
Email: jklemm@uni-bonn.de

Matin Qaim
Center for Development Research (ZEF), University of Bonn
Genscherallee 3
53113 Bonn, Germany
Email: mqaim@uni-bonn.de

Cover image: The plant tef grown predominantly in Ethopia.
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Abstract

Malnutrition persists globally in various forms, with further rising food demand, climate change, biodiversity loss, and land degradation representing interlinked additional challenges. Addressing these challenges requires building more resilient and sustainable agrifood systems to simultaneously improve production, nutrition, health, and environmental outcomes. The cultivation of diverse, nutritious, and climate-resilient crops, particularly neglected and underutilized crops (NUCs), offers an opportunity to help transform food systems sustainably. NUCs provide significant macronutrient and micronutrient benefits, and are often suited to marginal environments, enhancing biodiversity and resilience. However, NUCs remain underutilized due to production and demand-side challenges, including limited seed availability, inadequate infrastructure, and cultural barriers. This paper explores the potential role of NUCs in transforming food systems by highlighting key benefits and opportunities while also identifying current barriers to adoption. Nutrition-centered social behavioral change (SBC) strategies are emphasized as tools to improve consumer uptake. Insights from case studies in Cameroon and Tanzania showcase different interventions to promote NUCs and the gaps in policies within African countries. The paper concludes with policy recommendations to support the adoption of NUCs, contributing to sustainable, nutrition-sensitive, and climate-resilient agrifood systems. Collaborative efforts among governments, the private sector, research institutions, and NGOs are essential to address these barriers, advocate for NUCs benefits, and integrate culturally relevant social and behavioral change strategies.

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1. Introduction

The global discourse on agrifood systems has evolved and advanced rapidly, acknowledging the complexity within farms and beyond, such as in our food environments. Moreover, the impacts of the climate crisis on agrifood systems urge us to sharpen our focus on where, how, and by whom food is produced, processed, and consumed. In this regard, the UN Food Systems Summit 2021 marked a pivotal moment in how the world views food and agricultural systems— food and agriculture can no longer be considered within farm production only or separate from nutrition, health, and environmental outcomes. Integrated approaches centered on human and planetary health have become top political and societal priorities.

Globally, up to 730 million people are affected by chronic hunger, around 3 billion people suffer from micronutrient deficiencies, whereas over 2 billion people are overweight or obese (FAO et al., 2024). Meanwhile, food demand is expected to rise significantly, especially in Sub-Saharan Africa, where it is projected to increase by more than 50 percent by 2050. At the same time, climate change and land degradation are reducing crop yields, further worsening food insecurity and malnutrition.

Building resilient and sustainable agrifood systems that deliver nutritious diets for all requires a multitude of interventions across sectors. Perhaps most crucially and laying the foundation of robust agrifood value chains, it requires the cultivation of diverse, nutritious, and climate-resilient crops. In this context, the cultivation of neglected and underutilized crops (NUCs) — those crops with significant untapped potential to improve food and nutrition security, especially in the face of climate change – offers a unique opportunity for African countries to address nutrition, health, and climate challenges simultaneously and in an integrated manner.[1]

Many NUCs are nutrient-dense traditional varieties that have long been neglected by research and policy but hold great promise for strengthening food resilience and promoting dietary diversity. NUCs are typically grown in Africa, Asia, and South America and form part of local, traditional diets. Because little R&D has been directed towards NUCs over the past decades, breeding progress is lagging behind, limiting access to improved NUCs seeds and hence curbing uptake by farmers and consequently, consumers.

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[1] Different definitions of which crops are included and not included in the group of NUCs exist. Here, we use a recent classification by FAO and the African Union (Karl et al., 2024).

Box 1: Neglected, underutilized, orphan, minor, indigenous, opportunity, or wonder crops?

There are several terms used to describe indigenous and traditional crops, which are appreciated at the local levels mostly due to sociocultural preferences, but have **minor** roles in (inter)national food supply because their production volume is much lower than that of major/staple crops (Padulosi, 2021). The literature characterizes such food resources as the neglected and underutilized crops or species (NUCs/NUS), orphan crops, indigenous crops, minor crops, and forgotten crops to highlight their declining status and, conversely, as opportunity crops or wonder crops to emphasize their potential for economic and food system transformation. These crops are domesticated, semi-domesticated, or wild plant species that have been used for food and other purposes for centuries, but their significance has diminished over time. They are often characterized by their limited geographic distribution or use and lack of broader adoption or support from policymakers, technology providers, donors, breeders, and extension services.

Despite this, NUCs are valued for their importance in traditional agricultural systems, with many showing significant untapped potential to improve food and nutrition security and possessing climate resilience and tolerance to many biotic and abiotic stressors, including pests, diseases, drought, and extreme heat. Many NUCs also show remarkable tolerance for marginal lands and thrive in low-input conditions. As demand for plants with specific traits grows, the importance of these crops is being increasingly recognized, and efforts are underway to encourage their renewed adoption by farmers and integration into consumer diets (Khan et al., 2022; CGIAR, 2015).

In this paper, we chose to use the term “NUCS”, although “opportunity crops” too is increasingly accepted as a term to emphasize their potential (Box 1). NUCs are often very important in the countries where they are grown traditionally. These crops provide income for the poorest farmers and often serve as nutritious staples in the local diet; and, although lagging breeding technology has limited their production potential, NUCs are typically uniquely adapted to the environment in which they are grown.

Over the past few years, renewed attention to their multiple benefits has propelled NUCs to the top of the agenda among many international organizations, governments, and initiatives. One such initiative is The Vision for Adapted Crops and Soils (VACS), which aims to build a resilient food system grounded in diverse, nutritious, and climate-adapted crops grown in healthy, fertile soils (Karl et al., 2024). Some organizations, including the Global Crop Trust, are dedicated to conserving and making crop diversity available globally. Moreover, increased regional trade within Africa and the operationalization of the AfCFTA present important opportunities to boost economic growth, improve incomes and livelihoods, and strengthen the resilience of smallholder farmers, and rural and urban populations. It will be critical to have systems for technical and institutional innovations in the sector and regulations to spur intraregional trade while safeguarding the environment, maintaining quality standards, and ensuring that smallholder farmers are included in the resulting opportunities.

This paper explores the potentials of NUCs and the policy challenges for their wider adoption and use. The next section provides an overview of the benefits and opportunities of NUCs, focusing on their potential to strengthen resilience and contribute to more nutritious and healthier diets. Section 3 discusses the obstacles to the uptake of NUCs by farmers and consumers, emphasizing the need for increased investments in R&D to enhance seed availability and accessibility. A dedicated subsection highlights the key role of social and behavioral change strategies in increasing consumer uptake. This subsection provides valuable insights into the complexities of food consumption desirability and presents concrete examples of successful interventions that could be applied to NUCs. Section 4 analyzes two country case studies, showcasing efforts in Cameroon and Tanzania to leverage the benefits of NUCs. We highlight initiatives to accelerate the production of selected, context-specific NUCs. Additionally, several countries, in partnership with international organizations, have made significant progress in promoting the adoption of NUCs through targeted interventions—ranging from project-based approaches to those supported by adaptive policy environments. This paper also draws lessons from the recent "quinoa boom" in Peru and Bolivia, offering insights that can inform NUCs-focused strategies more broadly. Section 5 concludes with a set of policy recommendations.

2. Opportunities of NUCs: Nutritional benefits and climate resilience

There is a growing concern that current food production levels are insufficient to sustain the food demands and nutritional needs of a rapidly growing population. In an attempt to address this challenge, the development of supply chains for NUCs is increasingly acknowledged as one strong entry point for food system transformation, enhancing food security and nutrition while simultaneously addressing other socioeconomic and environmental challenges, such as poverty and climate change (Mabhaudhi et al., 2019; Sarker et al., 2022).

The benefits of NUCs in fostering more sustainable and equitable food systems are widely recognized:

Environmental benefits: Many NUCs demonstrate resilience to heat, drought, soil salinity, soil acidity, and pests and diseases (Cloete et al., 2013; Tadele and Assefa, 2012),

- **Social-cultural benefits**: NUCs represent the interaction between local knowledge and nutritional value of traditional and/or indigenous foods (Lara et al., 2019) and
- **Economic benefits**: NUCs contribute to livelihoods and income generation through their sale (Bharucha et al., 2010).

This paper focuses specifically on the nutritional benefits of NUCs and their potential to contribute to building climate resilience and preserving and enhancing biodiversity.

2.1. Nutritional benefits

Around 75 percent of the current global food supply originates from a narrow base of a few commercially relevant crops, with maize, rice, and wheat accounting for around half of the food choices and energy supplies (Farooq & Siddique, 2023; Joshi et al., 2018). Overreliance on a few staple crops has proven to be a high risk in the face of production shocks inflicted by climate change or socio-economic shocks and stressors, particularly within the African context (Laborde et al., 2023). This narrow focus has also obscured the importance of indigenous and traditionally grown food crops. In Africa, for instance, finger millet, pearl millet, fonio, and African rice are among some of the grains whose importance has diminished following the rise of internationally traded staples, influencing African farmers to shift their focus towards crops with higher economic value. This shift, however, has not adequately addressed the food supply deficit and malnutrition levels prevalent across the African continent. Fostering enabling environments that increase the uptake of numerous NUCs rich in macronutrients (e.g., protein, fats, and carbohydrates) and micronutrients (e.g., vitamins and minerals) is crucial to address the persistent food and nutrition challenges.

A greater supply of nutritious NUCs, such as indigenous vegetables, fonio, pearl millet, sweet potato, sesame, and pumpkin seeds, can help improve dietary diversity. For instance, these crops can help bridge the nutritional gaps left by animal-sourced foods, such as fish, ruminant meat, eggs, and milk, which, while being major sources of micronutrients, remain largely inaccessible to many Africans due to prohibitive prices (Beal and Ortenzi, 2022). Stevens et al. (2022) estimate that in Africa, 62 percent of children aged 6-59 months and 80 percent of (non-pregnant) women aged 15-49 years suffer from a deficiency of at least one of three essential micronutrients, namely iron (Fe), zinc (Zn), and vitamin A. Micronutrient deficiencies in poorer population segments are prevalent largely due to monotonous and cereal-based diets (Thompson & Amoroso, 2011; WHO, 2024). According to the most recent data, the prevalence of anemia among African women aged 15 to 49 was 38.9 percent in 2019, significantly higher than the global average of 29.9 percent for the same year. In children under the age of five, the prevalence was around 60 percent in Africa, compared to 40 percent globally (FAO et al., 2024; WHO, 2021).

Monotonous diets and limited access to animal-sourced foods in Africa are also associated with low protein intake, which can be remedied by a greater uptake of protein-rich NUCs, such as Bambara groundnut, chickpea, pigeon pea, and Lablab beans (Farooq & Siddique, 2023). Moreover, neglected dryland cereals like millets are crucial sources of carbohydrates, while NUCs like sesame and safflower are rich in dietary fat. Boosting the productivity of NUCs offers a potential avenue to reduce the persistent food supply gaps and increase the diversity of foods available to consumers, thus promoting healthy diets (Box 2).

Box 2: Defining a healthy diet

According to the World Health Organization (WHO), a healthy diet prevents all forms of malnutrition and helps lower the risk of noncommunicable diseases (NCDs) such as diabetes, heart disease, stroke, and cancer. The composition of such a diet varies depending on individual characteristics and existing food environments, but there exist basic guidelines to follow.

Leading health organizations recommend the following for a healthy diet (WHO, 2020):

- Calorie consumption should be in balance with the energy expended by the human body. The recommended daily energy intake is around 2500 calories for men and 2000 calories for women.
- Fruits and vegetables (at least 400 grams per day), legumes, nuts, and whole grains should be consumed daily.
- Daily protein intake should constitute at least 5 to 35 percent of total daily energy intake.
- Total fat should not exceed 30 percent of daily energy intake and industrially processed fats should be avoided completely. Unsaturated fats should be preferred over saturated and trans-saturated fats, with saturated fats accounting for less than 10 percent and trans-fat for less than 1 percent of daily energy intake.
- Daily carbohydrate intake should account for 45-65 percent of daily energy intake.
- Free sugars account for less than 10 percent of daily energy intake, with an ideal target of less than 5 percent.
- Daily dietary fiber should be at least between 14 and 34 grams.
- A healthy diet should contain minerals (e.g., iron, sodium, zinc, iodine, magnesium) and vitamins (A, B-complex, C, D, E, and K).
- Salt intake should be less than 5 grams per day equivalent to less than 2g of sodium per day. The consumed salt should be iodized.

Increasing consumer awareness of and access to NUCs can also help reverse the rising consumption of unhealthy foods and diets in Africa. Across the continent, food consumption patterns and food environments have experienced changes in recent decades driven by socioeconomic factors, such as demographic change, rapid urbanization, a growing middle class, and changing lifestyles (Glatzel et al., 2024; WHO, 2020). For instance, with the proliferation of supermarkets and a higher supply of (ultra)processed foods, consumers are increasingly shifting their preferences toward crops that are more accessible on the market and easy to prepare (Laborde et al., 2023). In particular, the influence of supermarkets on consumption choices has grown with their expansion from urban to peri-urban and rural areas in Africa (Demmler et al., 2018). However, despite this expansion, supermarkets predominantly serve wealthier households, while most low-income consumers continue to rely on traditional food sources (Khonje et al., 2019). There is also increasing consumption of more energy-dense foods that are high in fats, sugars, and salt/sodium, while intake of fruits, vegetables, and fiber-rich foods such as whole grains is decreasing (Glatzel et al., 2024; Laborde et al., 2023; WHO, 2020). Tapping locally adapted NUCs rich in micro- and macronutrients can contribute to a greater supply of healthy diets, alleviating the triple burden of malnutrition.

The limited likelihood of finding adequate macro- and micronutrients in a single crop or food group makes it necessary to rely on a wide diversity of food sources for a healthy and balanced diet. While various foods contribute to the overall nutrient intake, certain crop groups are particularly important sources of key nutrients, such as cereals and roots and tubers as major providers of energy, legumes as significant sources of proteins, fruits and vegetables as rich sources of micronutrients, and oil crops as primary contributors of unsaturated fats. Despite receiving little to no attention in comparison with mainstream crops, numerous NUCs in these food categories have the potential to complement their mainstream counterparts in tackling the persistent nutrition challenges.

Cereals and grains

Mainstream **cereals**, like maize, rice, and wheat, are the dominant energy sources in the human diet across countries worldwide. Despite significant investments in boosting productivity, most African countries remain net importers of maize, rice, and wheat. Many locally adapted neglected cereals contain comparable carbohydrates and energy content alongside other nutrients superior to those found in mainstream crops. For instance, compared to maize, rice, and wheat, some neglected cereals, including fonio (*Digitaria exilis* & *Digitaria iburua*), finger millet (*Eleusine coracana*), pearl millet (*Pennisetum glaucum*), durum wheat (*Triticum durum*), and African rice (*Oryza glaberrima*), are richer in complex carbohydrates (Akinola et al., 2020; Farooq & Siddique, 2023). In addition, teff, amaranth grain, pearl millet, and finger millet provide greater dietary **energy** than maize, rice, and wheat. Table 1 also shows that finger millet and fonio contain the highest **dietary fiber** among the reported cereal crops. In addition, amaranth, teff, and buckwheat, contain more **protein** than wheat, maize, and rice. Maize and rice also contain less protein than Bulrush millet and sorghum. Quinoa, a pseudo-cereal, which has gained prominence in the past few decades, is a complete protein, making it an exceptional source of all essential amino acids. Furthermore, teff, fonio, millets, and amaranth, **are gluten-free**, making them attractive options for consumers affected by celiac disease (Farooq & Siddique, 2023).

Fonio, pearl millet, amaranth grain, and red sorghum are exceptionally rich in mineral nutrients like **iron and magnesium**. In regions with favorable agroecological conditions, increasing the uptake of these neglected cereals can significantly complement the limited capacity of maize, rice, and wheat to provide adequate and diverse nutrients.

Table 1: Nutrient profiles of mainstream and neglected cereals

Nutritional content/100g	White fonio	Black fonio	Pearl millet	Bulrush millet	Finger millet	White sorghum	Red sorghum	Teff	Buckwheat	Amaranth grain	White maize	White rice	Wheat
Energy (kcal)	334	332	365	354	305	344	344	351	343	360	346	344	329
Carbs (g)	59.7	59.8	64.2	62.5	53.5	62.4	61.9	65.1	71.5	59.2	62.6	75.9	59.2
Protein (g)	7.1	8.3	9.3	9.8	7.38	10.1	10.1	13.3	13.25	14.7	9.7	7	12
Fat (g)	3.8	3	5.9	5.3	1.9	3.4	3.6	2.4	3.4	5.6	3.8	0.6	2.2
Dietary fiber (g)	16.4	16.4	9	8.8	22.6	11.9	11.9	8	10	7.5	11.5	3.6	12.2
Vit B3 (mg)	3.3	3.3	3.8	3.83	4.6	4.6	6.3	5.7	7.02	0.5	3.1	3.3	7.8
Vit B9 (mcg)	120	120	160	162	93	64	64	170	30	82	71	16	40
Ca (mg)	40	51	23	32	344	21	24	180	18	162	23	14	39
Fe (mg)	29.4	10	15.2	6.3	11.3	5.2	9.5	7.6	2.2	9.5	3.3	1.9	5.8
P (mg)	191	234	402	427	183	308	307	429	347	397	267	168	284
K (mg)	340	340	332	291	538	265	387	427	460	413	316	181	356
Mg (mg)	430	430	96	84	154	109	193	184	231	270	89	46	68
Sodium (mg)	8	8	12	4	2	6	9	12	1		15	3	5
Zn (mg)	2.79	3.8	2.58	4.14	1.7	2.08	1.97	3.63	2.4	2.5	2.2	1.45	2

Source: Food composition tables for West Africa (2019), Kenya (2018), and Tanzania (2008).
Notes: The grey columns on the right show reference mainstream crops. mg, milligram, mcg, microgram.

Legumes, nuts, and seeds

Among all plant food groups, legumes, nuts, and seeds account for the highest protein contents. **Proteins** play a beneficial role in physical and cognitive development during childhood (FAO, 2020), maintain a healthy body and skeletal mass, and strengthen the immune system (Cena and Calder, 2020). Proteins also support the regulation of metabolic functions, and improve both glucose and fatty acid metabolism (Papoola et al., 2023).

Unlike animal proteins, legumes are an affordable source of plant-based protein with additional ecological benefits to food supply through nitrogen fixation and soil health enhancement. Many legumes have protein contents estimated to be two-to-three times higher than that of cereals and are rich in complex carbohydrates, vitamins, minerals, and fiber (FAO, 2020). For instance, the protein share in edible portions of lentils, African locust bean, cowpea, chickpea, pigeon pea, and Bambara groundnuts is around 20 percent, indicating their potential to contribute to addressing the persistent protein supply gaps. Some of the other protein-rich but neglected legumes include Hausa groundnut (*Macrotyloma geocarpum*) and Lima bean (*Phaseolus lunatus L.*) (Akinola et al., 2020; Padulosi et al., 2013; Popoola et al., 2023). Alongside legumes, several neglected nuts (e.g., cashew nuts) and seeds (e.g., pumpkin seeds) are also rich in protein with contents upwards of 15 percent of the crops' edible portion.

Besides protein content, numerous neglected crops in this category hold other nutrition benefits that remain largely untapped. For instance, Fava bean, mung bean, chickpeas, and pigeon peas, are richer in vitamin A than soybean, groundnut and kidney beans. Table 2 further shows that the African locust bean, sesame seeds, pumpkin seeds, and lentils are richer in iron content than soybean, kidney beans, and groundnuts. The dietary fiber content in Bambara groundnuts, chickpeas, and pigeon peas is also 50 percent higher than the minimum required daily intake of about 14 grams. Many NUCs in this group are also rich in fat content, especially unsaturated and polyunsaturated fats. The consumption of **polyunsaturated fatty acids** found in Marama beans and Bambara groundnuts enhances heart and blood vessel functions and prevents the risk of heart disease and obesity (Hossain et al., 2016).

Table 2: Nutrient profiles of mainstream and neglected legumes, nuts, and seeds

Nutritional content/ 100g	African locust bean	African yam bean	Fava bean	Bambara groundnut	Chickpea	Cowpea	Cashew nut	Sesame seed	Pumpkin seed	Lentils	Mung bean	Pigeon pea	Soybean	Groundnut	Kidney bean
Energy (kcal)	406	316	341	323	323	325	591	601	567	318	324.91	310	385	574	305
Carbs (g)	37.8	46.7	58.29	33.6	34.3	49	27.8	4.9	9	41.3	49.56	41.6	13.8	17.4	40.6
Protein (g)	29	20.5	26.12	19.5	22.3	22.6	16.1	16.6	27.7	28.4	20.95	20.8	34.7	22.4	20.5
Fat (g)	13.8	1.5	1.53	5.9	5.1	1.5	45.4	54.1	45.4	0.6	1.35	2.1	15.9	44.2	2
Dietary fiber (g)	7.2	16.7	25	28.9	25.2	12.6	3.5	14.3	6	16.8	15.37	21	23.8	8.3	21.2
Vit A_ (mcg)	0	3	5.33	0	15	2	0	1	4	1	7.06	8	0	2	1
Vit B3 (mg)	10	6	2.83	4.1	2.1	5.5	4.4	7.6	12	2.54	5.67	5.5	9.9	19	5.57
Vit B9 (mcg)	380	480	423	100	400	420	68	100	58	132	620	340	380	110	272
Ca (mg)	330	40	103	53	235	82	48	777	62	83	89.43	121	206	45	106
Fe (mg)	14	4.1	6.7	3.2	6.8	6.2	7.4	11.2	8.3	7.4	4.42	4.5	6.5	3.5	6.4
P (mg)	319	253	421	267	284	416	438	631	1484	308	350.39	322	536	445	600
K (mg)	505	1290	1062	1160	1030	1120	489	458	579	629	1180	1660	1770	619	872
Mg (mg)	168	186	192	174	160	249	162	347	534	101	139.43	191	249	200	103
Sodium (mg)	49	2	13	2	25	22	95	45	5	11	9.09	3	5	6	22
Zn (mg)	5.15	2	3.14	2.4	3.37	3.55	5.34	2.1	8.89	4	1.62	2.49	4.8	2.61	2.78

Source: Food composition tables for West Africa (2019), Kenya (2018), and Tanzania (2008).
Notes: The grey columns on the right show reference mainstream crops. mg, milligram, mcg, microgram.

Roots, tubers, and plantains

Behind cereals, the plant food category comprising starch-rich roots, tubers, and plantains regularly features in African diets as a significant source of energy. Crops like Irish potato, cassava, and plantain are staple energy foods in many African countries, while yam, taro, and sweep potatoes have minor contributions to diets in most countries. Apart from having comparable energy contents, NUCs such as orange-fleshed and yellow-fleshed sweet potatoes provide additional benefits such as being rich sources of vitamin A, vitamin C, iron, zinc, and calcium. In particular, orange-fleshed sweet potato is a rich source of beta-carotene, with up to 791 mcg of vitamin A (retinol activity equivalents, RAE) per 100 g (Table 3). This makes it a crucial food for combating vitamin A deficiency, which is a leading cause of blindness and immune dysfunction in many low- and middle-income countries (WHO, 2024b). In addition, cocoyam is a rich source of potassium, and taro and water yam are rich sources of dietary fiber.

Table 3: Nutrient profiles of roots, tubers, and plantains

Nutritional content/100g	Yellow-fleshed sweet potato	Pale-fleshed sweet potato	Orange-fleshed sweet potato	White taro	White cocoyam	Water yam	Pale Yam	Yellow cocoyam	Irish potato	Fresh cassava	Dry cassava	Green plantain
Energy (kcal)	116	96	91	127	136	117	126	112	79	142	344	97
Carbs (g)	25.5	20.5	19.8	25.2	28.9	21.6	25.5	23.2	17.4	31.6	79.3	20.1
Protein (g)	1.5	1.5	1	2.7	3.3	2.4	2.3	3.3	1.5	1.3	1.7	1.4
Fat (g)	0.2	0.2	0.2	0.8	0.3	0.1	0.4	0.2	0.1	0.3	0.9	0.4
Dietary fiber (g)	3	3	3	4.1	2	9.7	5.6	2	1.7	3.7	5.6	3.6
Vit A_RAE (mcg)	127	5	791	4	0	3	3	93	0	2	2	0
Vit B9 (mcg)	52	26	11	22	23	26	27	23	10	24	44	19
Vit C (mcg)	31	22	31	8	8	15	13	8	14	30	7	23.3
Ca (mg)	40	34	54	26	15	15	26	15	6	37	67	7
Fe (mg)	1.9	1.3	0.9	1.6	0.7	0.8	1.6	0.7	1	1.5	1.4	0.8
K (mg)	283	283	288	350	531	281	383	531	469	167	394	322
Sodium (mg)	20	31	20	17	9	6	7	9	8	2	5	10
Zn (mg)	0.54	0.54	0.62	0.61	0.34	0.43	0.64	0.34	0.37	2.05	0.44	0.23

Source: Food composition tables for West Africa (2019), Kenya (2018), and Tanzania (2008).
Notes: The grey columns on the right show reference mainstream crops. mg, milligram, mcg, microgram.

Vegetables and fruits

The consumption of vegetables and fruits is commonly associated with micronutrient and dietary fiber intake. Traditional vegetables like Moringa leaves, spider plant leaves, amaranth leaves, cassava leaves, jute mallow, and sweet potato leaves contain high amounts of vitamin A (Table 4).

Table 4: Nutrient profiles of mainstream and neglected fruits and vegetables

Nutritional content/100g	Cassava leaves	African eggplant	Fresh Moringa leaves	Amaranth leaves	Jute mallow	Sweet potato leaves	Spider plant leaves	Black African nightshade leaves	Okra leaves	Okra fruit	Orange-flesh squash	White cabbage	Carrot	Red tomato
Energy (kcal)	93	32	81	40	48	50	44	31	45	34	34	26	34	22
Carbs (g)	9.1	3.9	4.5	3	3.2	4.9	1.9	1.3	5.1	4.2	6	3.6	5.5	3.3
Protein (g)	7.6	1.3	8.4	4.1	4.2	4.6	4.8	3.8	2.5	1.7	1	1.6	0.9	1
Fat (g)	1.1	0.4	1.4	0.4	0.3	0.2	0.9	0.1	0.6	0.2	0.1	0.1	0.2	0.2
Dietary fiber (g)	7.9	4	8.2	3.8	8.3	5.3	4.3	4.3	4.9	4.1	2.4	2.2	3.2	1.4
Vit A_RAE (mcg)	574	11	1640	451	275	285	531	2	67	43	71	0	637	26
Vit B1 (mg)	0.25	0.07	0.22	0.05	0.12	0.1	0.1	0.06	0.16	0.04	0.05	0.04	0.04	0.04
Vit B2 (mg)	0.46	0.11	0.77	0.19	0.31	0.28	0.09	0.32	0.4	0.08	0.02	0.04	0.05	0.04
Vit B3 (mg)	4.2	0.8	2.6	1.4	1.5	1.5	2.4	2.18	0.7	1.2	0.6	0.6	0.7	0.5
Vit B6 (mg)	0.48	0.06	1.2	0.21	0.6	0.19	0.35	0.27	0.24	0.27	0.25	0.13	0.25	0.08
Vit B9 (mcg)	120	33	40	76	120	80	350	404	57	88	8	15	17	25
Vit C (mcg)	33	2	221	67	74	11	64	36	64	28	8	54	7	25
Vit E (mg)	0.42	0.09	0.27	0.44	0.42	0.96	2.5		0.42	0.49	0.41	0.05	0.72	
Ca (mg)	298	12	595	368	282	78	268	100	303	87	19	43	36	8
Fe (mg)	5.5	1.1	10.3	7.2	7.2	3.6	6.9	8.6	0.6	0.8	1	1.2	0.8	0.9
P (mg)	145	29	91	69	111	84	46	68	70	54	33	45	48	25
K (mg)	711	239	405	545	273	569	478	421	297	382	280	313	225	126
Mg (mg)	73	24	68	160	77	70	92	41	59	77	15	9	14	9.5
Sodium (mg)	6	4	9	7	12	6	19	10	6	11	0	13	35	21
Zn (mg)	1.29	0.23	1.2	0.66	0.76	0.29	0.75	0.65	0.46	0.55	0.29	0.16	0.25	0.37

Source: Food composition tables for West Africa (2019), Kenya (2018), and Tanzania (2008).
Notes: The grey columns on the right show reference mainstream crops. mg, milligram, mcg, microgram.

Other NUCs in this group, such as okra fruit and its leaves, African eggplant, and black nightshade, provide superior content of dietary fiber when compared to mainstream vegetables like cabbage, tomatoes, and carrots. Moreover, underutilized crops like African pear/Safou (*Dacryodes edulis*), gingerbread plum (*Parinari spp, Neocarya marcophylla*), and egusi (*Cucumeropsis mannii*) are rich in edible fat (Akinola et al., 2020), providing a readily accessible energy source with no processing requirements. Wild watermelon (*Citrullus lanatus*) contains Ca, Fe, Mg, P, many vitamins, and carotenoids, including lycopene (Abbas et al., 2023; Singh et al., 2022). Baobab (*Adansonia digitata*) is known to be rich in Fe, Ca, K, vitamin C, and many other micronutrients that enhance its biological properties, including antimicrobial, anti-malarial, anti-diarrheal, anti-anemia, anti-asthma, antiviral, antioxidant, and anti-inflammatory properties, among others (Abbas et al., 2023; Rahul et al., 2015).

2.2. Climate resilience, ecological adaptation, and biodiversity benefits

Africa's food systems are severely affected by the global climate crisis, with significant impacts on food security, nutrition, livelihoods, and incomes. Since 1961, climate change has caused a 34% decline in agricultural productivity growth (IPCC, 2022). Over the past 50 years, droughts have claimed over half a million lives and caused economic losses exceeding US$70 billion. During the same period, flood-related hazards have also claimed more than 20,000 human lives (WMO, 2022). If global warming surpasses the 2°C threshold, crop yields could further decrease by up to 20 percent globally, and more in sub-Saharan Africa (Carleton, 2022). Additionally, extreme weather events may cost the African continent US$50 billion annually by 2050 (GCA, 2021).

Anticipated changes, such as shorter growing seasons and increased water stress, are likely to intensify the challenges facing food systems in Africa. Moreover, there is evidence suggesting that climate change will reduce the nutritional contents of certain crops. Recent estimates show that higher carbon dioxide (CO_2) concentrations (beyond 550 ppm compared to the current global average of around 440 ppm) in the atmosphere reduce the protein, iron, and zinc contents of many food crops, including rice and wheat, by 3 to 17 percent (Medek et al., 2017; Smith and Myers, 2018). The experimental results by Medek et al. (2017) indicate that under an elevated CO_2 scenario (e.g., 550 ppm), the protein content in rice, wheat, barley, and potatoes decreased by 7.6 percent, 7.8 percent, 14.1 percent, and 6.4 percent, respectively. Their meta-analysis findings also reveal declines in protein content of approximately 3.4% for root vegetables, 3.5% for legumes, 0.8% for oil crops, and 23% for fruits. They also predict that, under the prevailing emission trends, an additional 148 million of the global population could face protein deficiency because of elevated CO_2 concentration by 2050. In sub-Saharan Africa, an additional 24.6 million people could be at risk of protein deficiency by 2050, up from the current 613.6 million people already affected (Medek et al., 2017).

It is crucial for African countries to adapt to anticipated climate risks and shocks as part of a comprehensive strategy to enhance resilience. This includes mitigating climate change by reducing greenhouse gas emissions and implementing nature-based adaptive solutions for emission reductions. These efforts are further complicated by natural resource depletion and unprecedented biodiversity loss (IPBES, 2019). One pathway to addressing the impact of climate change on nutrition can be through the increased adoption and integration of NUCs in diets. Several NUCs are climate resilient, ecologically well adapted, resource-efficient, and contribute to biodiversity improvement. Their resilience to heat, drought, soil salinity, soil acidity, and pests and diseases (Tadele and Assefa, 2012) showcases their ability to withstand increasingly unpredictable weather and thrive in marginal environments.

For example, fonio has been shown to be fairly resilient to various biotic and abiotic stresses. This millet species is known to be a fast-growing crop, producing grains earlier than most mainstream crops (Alercia, 2013; Dachi and Gana, 2008; Farooq and Siddique, 2023). Fonio grows relatively well in unfavorable terrains, low-nutrient soils, and water-scarce environments. It is also the least susceptible to pests and diseases among all the millets grown in semi-arid and arid regions (Farooq and Siddique, 2023). Addressing constraints to its mass production, such as outdated production and processing technologies and low yields (Alercia, 2013; Maji et al., 2003), could significantly contribute to transforming food systems in arid and semi-arid regions like West Africa and the Sahel. Historically, fonio has been a major cereal in these regions, but over the last several decades has been relegated to a substitute crop, primarily relied upon when other crops fail (Dachi and Gana, 2008; Farooq and Siddique, 2023). Initiatives to increase the uptake of fonio are summarized in Box 3.

Box 3: Fonio, a cereal with a huge potential yet to be unlocked

Predominantly grown in West Africa as a staple food for many millions of people, fonio is a fast-growing small millet with high adaptation in marginal environments; it has a high nutrient density, higher iron content than maize, rice, and wheat, and is gluten-free, yet remains underutilized (Farooq and Siddique, 2023; Lipton, 2024). The World Food Program also hails fonio as climate-resilient “superfood” for food security and income generation in West Africa. Due to various initiatives, the uptake of fonio seems to be increasing.

In Senegal, Sanoussi Diakité, a mechanical engineer, has developed a fonio machine that processes the crop 30 times faster than manual processing. By 2024, his company had sold around 300 machines in eight countries, including Senegal, Mali, Benin, and Guinea (Cruz et al., 2016; WIPO, 2014). In addition, his company organizes awareness campaigns and offers training programs, with a strong focus on engaging the youth and women producer organizations to stimulate fonio uptake (WFP, 2024a).

Fonio’s visibility on the international market has also increased in the recent past, in part, thanks to Yolélé Foods, a US-based company run by the Senegalese Chef Pierre Thiam. Since 2017, the company has partnered with West African fonio farmers and has invested in a fonio processing factory in Mali to increase the output of edible grain from 1 ton per workday to 3 tons per hour. These initiatives have boosted fonio’s supply to the international market, especially in the USA (Laborde et al., 2023; Lipton, 2024). Yolélé Fonio, the company’s flagship product, is marketed as “a gluten-free packaged cereal with triple the protein, iron, and fiber of brown rice, which cooks in just 5 minutes!” (Pierre Thiam Group, 2024). The product is available in large-scale retail markets in the USA, such as Target and Whole Foods (Lipton, 2024). The company also produces fonio chips and fonio pilafs, catering to several niche markets, which highlights fonio's culinary versatility.

Furthermore, there has been a rise in multilateral initiatives to promote the uptake of fonio alongside other small millets. FAO's declaration of 2023 as the year of millets put fonio into the spotlight, especially in its Global Chefs Challenge, a social media campaign featuring 250 millets recipes, and its published millets recipe book, featuring 23 millets recipes. Similar efforts include an FAO collaboration with Chef Fatmata Binta in capacity development of around 100 fonio-producing women in Ghana to enhance their productivity and market access. The Vision for Adapted Crops and Soils (VACS) initiative promotes investments in the sustainable production of consumption of fonio among other climate-resilient and nutritious crops (FAO, 2024b).

Greater advances in fonio's production technology, including breeding for high-yield varieties, deeper penetration on the international market, and an increased level of awareness about its high nutrient content will be crucial for fully unlocking its potential.

Other cereals known to withstand harsh environmental conditions include finger millet and teff. Finger millet is highly adapted to the semi-arid tropics of Africa and Asia. It is particularly known as dagusa in Ethiopia and rapoko in South Africa, where it thrives under environmental stress (Farooq and Siddique, 2023). Moreover, finger millet possesses genetic traits that enhance its resilience to climate-related challenges, enabling it to withstand various environmental stresses such as drought, salinity, waterlogging, nutrient-poor soils: the crop is also resistant to various fungal and bacterial infections (Nadeem et al., 2020). One particular feature of finger millet is its long shelf life and ability to resist post-harvest pest infestations (Latha et al., 2005). On the other hand, teff, mostly grown in Ethiopia, is known to thrive in diverse ecological conditions, including areas experiencing moisture stress and waterlogging, and is reported to be resistant to plant diseases and grain storage pests (Sharma and Chauhan, 2018; Seyfu, 1997).

Additionally, various underutilized millets (e.g., finger millet, pearl millet, and Barnyard millet) are recognized for their significant contributions to agrobiodiversity. In addition to their ability to thrive in poor soils and endure drought and other extreme weather conditions, these millets possess deep rooting systems that help stabilize and enhance soil structure, manage soil nutrients, contribute organic matter, and prevent erosion (Raj et al., 2024). Incorporating millets into crop rotation and intercropping systems is recognized as a sustainable approach that promotes soil biodiversity, controls pest and disease cycles, provides a habitat for insects, other animal pollinators, and biological control organisms (Nicholls and Altieri, 2013), and reduces the dependence on chemical fertilizers (Raj et al., 2024). The low demand for chemical fertilizers and pesticides in millet farming systems is in contrast with the conventional farming systems of many mainstream crops (e.g., maize, wheat, and soybean). High intensity of chemical inputs is known to threaten pollinators and pollute water streams, endangering terrestrial and marine biodiversity (Nicholls and Altieri, 2013). Besides, thanks to their wide genetic diversity, cultivating many locally adapted millet types preserves a valuable genetic resource for future generations (Samtani et al., 2024).

Some neglected roots and tubers, such as taro and sweet potato**,** are also regarded as climate-smart because of their notable drought tolerance. In their experimental study on three South African taro (*Colocasia esculenta (L.) Schott*) landraces, Mabhaudhi and Modi (2015) found that the Umbumbulu landrace, in particular, is highly adapted to growing under water stress conditions through its ability for plant physiological regulation, reducing chlorophyll levels, limiting canopy size, and shortening its growth period. This resilient crop offers a reliable food source with the potential to withstand recurring drought spells in the Southern Africa region (Kubik and May, 2018; WFP, 2024b). Sweet potato (*Ipomoea batatas*) is known for its high adaptability in tropical and subtropical regions, where it performs well in low-input farming systems, exhibits strong drought tolerance, and has significant environmental flexibility, enabling it to be planted and harvested year-round, particularly in areas without frost (Chivenge et al., 2015; Motsa, 2015).

Box 4: The ecologically adapted and nutritious biofortified orange fleshed sweet potato (OFSP)

Staple crop biofortification is one of the robust pathways to tackling hidden hunger, especially for the hundreds of millions of smallholder farmers who rely primarily on their harvests for food (HarvestPlus, 2024a). For instance, regular consumption of vitamin A-biofortified orange-fleshed sweet potato (OFSP), a drought tolerant, high yielding, and virus-resistant variety, can provide up to 100 percent of vitamin A requirements among children and women of reproductive age (HarvestPlus, 2024b). By 2021, 1.3 million households in Africa, Asia, Latin America, and the Caribbean region were growing vitamin A-biofortified OFSP, providing them with adequate access to vitamin A to combat diarrheal diseases, measles, and blindness in case of extreme vitamin A deficiency (HarvestPlus, 2024b). In addition, this variety's ability to retain its nutritional contents after processing has increased its appeal for various value chains, such as processing it into baby food, flour, and bread. There has been a noticeable uptake of OFSP in Africa, especially Angola, Burkina Faso, Burundi, Côte d'Ivoire, Ethiopia, Ghana, Kenya, Madagascar, Malawi, Mozambique, Rwanda, South Africa, Tanzania, Uganda, and Zambia. Given its high adaptability to a wide range of environments, ability to grow between 0–2,500 meters of altitude, lower input and labor requirements compared to mainstream crops (e.g., maize), resilience to drought and poor soils, year-round cultivation potential, and nutritional content—including vitamins B, C, and E, as well as moderate levels of iron and zinc (Chivenge et al., 2015; CIP, 2024)—sweet potato offers significant potential for vitamin A biofortification. This additional nutritional benefit could help elevate its status as a neglected food crop. With increased uptake, it could play a crucial role in addressing hidden hunger in developing countries, where 95% of the crop is grown (CIP, 2024).

Underutilized legumes and vegetables are also reported to have physiological characteristics enabling them to adapt to harsh environmental conditions. Bambara groundnut, an annual legume crop, is regarded among the most drought-tolerant crops in Africa (Mwale et al., 2007) and grows in several regions of the continent, ranging from Bambara, a region in Northern Niger, to southern African regions (Chivenge et al., 2015). Cowpea is also known to be drought-tolerant (Modi and Mabhaudhi, 2013), with its long taproots enabling it to have easy access to deep water and nutrient resources, enhancing its resilience, especially during warm growing seasons (Chivenge et al., 2015). Furthermore, amaranth (*Amaranthus spp*) is highly adaptable to water-scarce environments (Chivenge et al., 2015), withstand acidic soils (Palada and Chang, 2003) and salinity stress (Omami, 2005), and exhibiting high water efficiency through quick development of the root, shoot, and leaf systems (Liu and Stützel, 2004). Other neglected vegetables, such as African nightshade, African eggplant, bitter leaf, Ethiopian mustard, and jute mallow, are known to require less land, are resistant to droughts, floods, pests and diseases, and can be grown in shorter cycles than most mainstream crops (WVC and AUC, 2024). They are also more adaptable to the African ecosystems than common vegetables, such as carrots, tomatoes, and broccoli (AU, 2021; WVC and AUC, 2024).

Many underutilized vegetables and legumes are also known to be endowed with high potential for ecological and biodiversity benefits. The drumstick tree (*Moringa oleifera*), also known as a "miracle tree", is noted for its numerous ecosystem services. On top of its resilience to poor soil conditions and drought, it is commonly used in agroforestry systems for intercropping as it improves soil fertility, stabilizes degraded land, sequesters carbon, and contributes to nutrient cycling and phytoremediation[2] (Horn et al., 2022). Moringa trees also contribute to environmental sustainability when planted as hedges, providing a habitat for birds and insects, contributing to the pollination of diverse crop species, and enhancing the overall biodiversity in agroecosystems (Shailemo, 2010). A further biodiversity benefit of NUCs, especially neglected legume crops, is nitrogen fixation, which enriches the soils and promotes the growth of diverse crops in rotation or intercropping systems. Starting with Bambara groundnut, this legume is known to be efficient at fixing atmospheric nitrogen into the soil, making it a crucial option for crop rotation with staple cereals that usually require significant amounts of fertilizers to grow productively (Chivenge et al., 2015). Similarly, cowpeas are reported to be effective at nitrogen fixation, even under adverse climatic conditions (Rasche et al., 2023).

[2] Phytoremediation refers to the use of living plants to clean up soil, air and water contaminated with hazardous contaminants.

3. Constraints limiting the adoption of NUCs

Despite being endowed with many desirable attributes (see section 2), the potential of many NUCs remains untapped. This is largely because of various supply- and demand-side challenges. On the supply side, production constraints include farmers' limited access to essential inputs and inadequate market opportunities for NUCs. On the demand side, consumer-related challenges involve issues of availability, accessibility, affordability, and desirability of NUCs.

3.1. Production challenges

The low yields often associated with NUCs represent a significant constraint limiting their production. Furthermore, inadequate commercialization and marketing, coupled with poor infrastructure, pose other significant challenges on the supply side. A confluence of factors, such as poor seed availability and production technologies and limited knowledge, further undermine the economic potential of NUCs. This section seeks to explore the factors limiting the uptake of NUCs on the supply side. However, it is essential to understand that these factors often interact with each other, and also with demand-side constraints, meaning that they should be addressed through holistic and integrated approaches.

Seed availability

Limited access to quality seeds can prevent farmers from growing NUCs, as quality seeds for many of these crops are not widely available in markets. African crop producers obtain around 90 percent of their planting materials from self-produced seeds (or vines) or from relatives, neighbors, and local informal markets, while they source less than 10 percent from the formal seed sector (ACB, 2019). The quality of self-produced seeds is known to deteriorate over time, mainly because indigenous practices for retaining and enhancing seed quality are rarely supported, leading to significant declines in productivity (ACB, 2019). However, crop producers who attempt to buy improved seeds from (semi)formal sources also face several obstacles, especially a trade-off between seed quality and easy access (Ayenan et al., 2021). These challenges are particularly pronounced in neglected crop production systems, hindering adequate adoption and supply of NUCs.

The persistent scarcity of high-yielding seed varieties remains one of the key obstacles to increasing the adoption of NUCs. According to Ayenan et al. (2021), in Africa, formal seed systems remain mostly underdeveloped with a limited number of private-sector mediated seed systems that are formal, well-regulated, and organized from breeding to delivering seeds of certified and registered varieties.

Informal seed systems remain predominant and consist of farmer-saved seeds and seed purchases from local markets. Community-based seed systems are semi-formal in their approach to seed production and distribution. In their analysis of these seed systems, Ayenan et al. (2021) find that seeds provided through informal seed systems generally have lower and inconsistent quality than those from formal seed systems, with the highest quality observed in seeds from private-sector mediated systems. Additionally, Ayenan et al. (2021) document that community-based seed systems provide better access to seeds than the other formal and informal systems. A review by El Bilali et al. (2024) on the conservation and promotion of NUCs indicates that African informal seed systems tend to be unreliable at supplying good-quality and early-germination seeds and efficient seed packaging and labelling. These constraints discourage farmers from cultivating NUCs, which calls for more efforts to formalize and optimize NUCs seed systems to stimulate greater NUCs seed supply and adoption. The slow progress of formal seed systems across Africa remains one of the key challenges in enhancing the seed availability of NUCs. Coupled with unfavorable legislation, this also diminishes the potential for NUCs seed businesses (Ayenan et al., 2021).

Appropriate legislation and greater collaboration across the science-agribusiness-policy interfaces are essential to increase the functionality of seed distribution systems. Seed availability challenges have persisted for several years, forcing many NUCs producers to rely on self-produced seeds and limiting the broader production potential. These challenges can be addressed through multilateral initiatives that promote the efficient collection and distribution of improved seeds, such as the Crop Trust's Seeds for Resilience project detailed in Box 5. This has to be accompanied by enhanced investments in demand-driven research and development, the lack of which has been another major obstacle to mainstreaming NUCs in African agricultural systems.

Box 5: Seeds for Resilience (SFR): A Crop Trust project supporting the seed/crop diversity at gene banks in sub-Saharan Africa

Starting in 2019, this five-year project aims to strengthen national gene banks in Ethiopia, Ghana, Kenya, Nigeria, and Zambia. Funded by the Federal Government of Germany (BMZ) through the German Development Bank (KfW) and implemented by Crop Trust, the project provides both financial and technical support to national gene banks to sustainably improve the international standards, safety, and availability of their conserved seeds.

The project has embraced a local capacity-building approach that delivers international impact. It fosters a gene bank governance system that streamlines seed data documentation and exchange. It also encourages user-driven collection and delivery of seed samples, for instance, through participatory trials among interested farmers and breeders, which promotes the selection and breeding of crops that are best suited to local conditions and needs. The project aims to achieve international availability of climate-smart, nutritious, and more productive crop seeds, which improve food security and the livelihoods of African farming communities.

Several NUCs are included in this project's focus crops varying across countries:

- In Ethiopia, the project works on barley, coffee, enset, faba bean, and sorghum
- In Kenya, it focuses on cowpea, finger millet, pearl millet, pigeon pea, and sorghum
- In Zambia, it works on beans, cassava, cowpea, sorghum, and sweet potato
- In Ghana, it works on cassava, cowpea, eggplant, Bambara groundnut, maize, and rice
- In Nigeria, it focuses on cowpea, okra, nightshade, pearl millet, sorghum, and yam

The SFR project has significantly increased the availability of NUCs seeds in partner countries. Crop Trust (2024b) has documented that in Kenya, the project has partnered with the Genetic Resources Research Institute (GeRRI) to revive the use of neglected traditional drought- and pest-resistant crops, some of whose seeds have been sent to the Svalbard Global Seed Vault for ex-situ conservation (Crop Trust, 2024). For example, this collaboration has increased smallholder farmers' access to a sorghum variety, the red-headed sorghum Okoto, which is less vulnerable to bird damage. In **Nigeria**, the National Centre for Genetic Resources and Biotechnology (NACGRAB) in Ibadan is the project's partner gene bank, which houses more than 11,000 crop/seed samples. With Crop Trust's support, the gene bank staff have more actively carried out seed viability tests on several crops, including okra, and collaborated with the so-called "user engagement groups" of farmers to test the ability of collected seed varieties of crops, such as sorghum and cowpea, to cope in different environmental conditions in Oyo, Niger, and Kano states. This has helped farmers to select climate-resilient and high-yielding varieties, which the gene bank is currently prioritizing in its conservation efforts. In **Ghana**, CSIR-Plant Genetic Resources Research Institute (CSIR-PGRRI) is supported by Crop Trust to enhance crop diversity, including that of Bambara groundnuts. The gene bank houses around 90 Bambara groundnut landraces but only four are used by Ghanaian farmers. The SFR project is helping the gene bank to distribute many Bambara groundnut varieties to interested farmers and researchers to select the most suitable varieties for multiplication. The gene bank is also testing all the 90 varieties on its research field to examine various agronomic traits that require urgent improvement. CSIR-PGRRI also houses other NUCs species, including cowpea, eggplant, jute mallow, hibiscus, and amaranth. The gene bank has increased its work on the conservation of indigenous leafy vegetables (ILV). The SFR project has created plots to examine 20 accessions for many ILV, enabling farmers, traders, and processors to select their preferred crop traits for multiplication, such as maturity time, and leaf color and shape. In **Ethiopia**, the SFR project supports the Ethiopian Biodiversity Institute (EBI) to upgrade its gene bank, conserving over 90,000 accessions of different species, including faba bean, sorghum, and unique collections of Arabica coffee, tubers and spices. The gene bank has ramped up its collaboration with interested breeders and farmers interested in once-forgotten crop varieties, is more actively collecting seeds from farmer fields, and is on track to increase the number of seed varieties shipped abroad for ex-situ conservation.

By 2024, the project's final year, the seeds for resilience project has helped more than 1300 farmers to access more than 300 improved crop varieties across Africa (Crop Trust, 2024b; The Guardian, 2024). More investments and multilateral collaborations will be crucial to ensure that the 28 existing national seedbanks in Africa attain the global standard of efficiency and can sustain themselves. In addition, more functional and sustainable national gene banks must be established in remaining countries to achieve various food system transformation goals in Africa. This needs to be accompanied by strengthening national seed systems, and promoting enabling environments that encourage access, affordability, and utilization of quality seeds.

NUCs-focused research and development

The prevailing limited availability of and access to quality NUCs seed varieties mainly stems from insufficient investment in research and development (R&D). Improving the seed availability and quality primarily involves the conservation of gene pools and breeding programs (Bohra et al.,2022). The development of quality seeds of NUCs has lagged behind that of mainstream crops (e.g., maize, rice, and wheat) for many years, with policies and private initiatives allocating scarce funding to the conservation and sustainable use of the genetic resources of NUCs (El Bilali et al., 2024).

The production potential of NUCs is restricted by low-quality seed material with little biotechnological improvement (Ali and Bhattacharjee, 2023). In favorable soil conditions, improved seed varieties are estimated to contribute up to 50 percent of crop productivity (ACB, 2019). However, the productivity of numerous NUCs remains poor due to scarce R&D investments in high-yielding varieties. For instance, many NUCs, such as Bambara groundnut, lablab bean, and moth bean are predominantly grown using traditional low-yielding landraces, hindering their production potential (Majola et al., 2021).

The production of many NUCs is further limited by seed dormancy. For example, a study by Silindile and Modi (2017) showed that farmers resort to chemical and mechanical scarification[3] to overcome the Bambara groundnut's seed dormancy. However, they report that these approaches do not significantly influence vigorous seedling establishment. A recent review by N'Danikou et al. (2024) also indicates that seed dormancy remains a major challenge in underutilized African vegetables, such as bitter leaf, African lettuce, jute mallow, okra, African eggplant, and blackjack. Many other NUCs, such as pigeon pea, are challenged by late maturity, often taking more than half a year, limiting their appeal to farmers. The breeding program by the Kenya Agricultural and Livestock Research Organization (KALRO) released an improved pigeon pea variety called "Mituki" in 2018, which matures in four-and-a-half months and can be harvested three times a year (Oluoch, 2024). This variety also has other traits preferred by farmers and markets, such as larger grains and pods, which facilitate easier shelling. More R&D efforts to address late maturity in other NUCs, such as the winged bean, African yam bean, and Proso millet (Farooq and Siddique, 2023), will be crucial in increasing the uptake of NUCs.

Furthermore, many NUCs are vulnerable to weeds and certain pests and diseases with little progress in breeding for resistance against such biotic risks.[4] Those risks include the legume pod borer affecting beans and peas, Striga (witchweed) affecting sorghum and millets, and groundnut rust, among others (CABI and ASHC, 2015). Some notable efforts addressing these vulnerabilities include Nigeria's release

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[3] Seed scarification is the process of altering the seed coat to allow quicker water absorption and improve rates of germination.

[4] Many NUCs are well-adapted to stresses that have existed for long in a particular region. However, more intensive production and environmental change lead to new types of stresses for which adaptation is needed.

of the pod borer-resistant (PBR) cowpea variety in 2019 (AATF, 2024a) and the forthcoming release of another PBR cowpea cultivar in Ghana, which is expected to increase cowpea production by four-fold from its current yield level of 2 tons per hectare (Alliance for Science, 2022). The deadly pod borer pest can cause up to 80 percent crop loss, and it also affects other NUCs, such as beans, broad beans, pigeon pea, green gram, and sorghum (CABI, 2013). AATF is also working with the International Institute of Tropical Agriculture (IITA) and the National Agricultural Research Organization (NARO) of Uganda to develop a bacterial wilt resistant banana variety to increase this neglected crop's resilience and productivity (AATF, 2021). NUCs varieties that are resistant to biotic stressors are necessary to increase the availability of nutritious crops and minimize the adverse effects of chemical inputs (e.g., pesticides), including biodiversity loss and pesticide poisoning, which adversely impact farmers, consumers, and the environment (Alliance for Science, 2022).

One important point to mention is that the PBR cowpea variety released in Nigeria is a genetically engineered type developed by not-for-profit organizations targeting the benefit of smallholder farmers. New genomic techniques, and gene editing in particular, offer the potential to increase the precision and speed of plant breeding in a variety of species, which is of particular relevance for NUCs, as these have been neglected in traditional breeding programs for a long time. Using gene-editing tools for developing pest and disease resistance is an active field of research and testing in a large number of crops, including several NUCs on the African continent.

Beside pests and diseases, the production of some NUCs is also hindered by certain agronomic characteristics, whose improvement have received scarce R&D investments. Although many NUCs are climate resilient, their physical features are vulnerable to a few other abiotic stressors, such as heat, drought, and wind. For instance, fonio and proso millets are highly susceptible to shoot lodging and seed shattering (Farooq and Siddique, 2023). Because of seed shattering, fonio's grain losses can amount to as much as 25 percent when harvests are delayed (Organic Africa, 2022). Moreover, one study has shown that in some fonio varieties, lodging can affect up to 65 percent of the plant population (Addai et al., 2022). Little progress has been made in developing millet varieties that are resistant to shoot lodging and seed shattering, which significantly worsens their yields and hinders the application of mechanized harvesting (Farooq and Siddique, 2023).

These challenges highlight the need for crop selection and breeding interventions to enhance desirable seed/crop qualities and appeal to farmers. This can involve the conservation and multiplication of high-quality varieties and the improvement of the crops' genetic composition through breeding. These interventions are gaining prominence among initiatives working on the revival of NUCs.

Box 6: Genetic conservation

In recent years, some research centers initiated genetic conservation and improvement projects on NUCs to advance their role in the food and biodiversity provision. To this end, there have been efforts to conserve the gene pools of several NUCs. Gene pools comprise all plant genetic resources of certain NUCs, including in-situ (in the original habitat) and ex-situ (outside the original habitat) accessions. Gene banks are one form of collecting genetic resources ex-situ. The CGIAR holds gene banks across the world to conserve plant genetic resources (Figure 1). For example, the Alliance Bioversity and CIAT preserves genetic resources of neglected crops such as beans, banana, cassava, and tropical forages (CIAT, 2024). The World Vegetable Centre gene bank preserves 133 genera and 330 species of vegetables from 155 countries, including indigenous vegetables (WVC, 2024). The International Center for Agricultural Research in the Dry Areas (ICARDA) supports the development of climate-resilient plant varieties by conventional and molecular breeding. Crop breeding by ICARDA involves introgression from new alleles from landraces and wild relatives into elite germplasm. ICARDA's nursery systems develop and distributes improved varieties of some NUCs, such as chickpea, lentil, faba bean, and durum wheat globally (ICARDA, 2024).

The African Orphan Crops Consortium (AOCC) works to conserve NUCs genetic material. Since 2011, the Consortium has endeavored the genome sequencing of 101 NUCs, and by 2019, it had accomplished the sequencing of six species, with other six near completion and other 20 exhibiting significant progress (Hendre et al., 2019).

The Global Crop Trust provides tools and support for the management of national gene banks, and organizes the backup of crop seeds in the Svalbard Global Seed Vault. It mobilizes resources to protect national gene banks during crises, such as conflicts and war, or climatic disasters, which might threaten accessions. The Global Crop Trust supports conservation work in over 80 countries. By acknowledging that conservation alone is not sufficient, the Crop Trust launched the "BOLD" project aiming to strengthen the availability, accessibility, and skills and knowledge to use plant genetic resources, e.g. through participatory breeding. The BOLD project involves work on the conservation and breeding of several NUCs, such as Bambara groundnut, breadfruit, Brassicas, finger millet, grass pea, taro, and yams across African countries like Benin, Ghana, Tanzania, and Uganda (Crop Trust, 2024).

Figure 1: Gene banks of the CGIAR (Gene banks | CGIAR Gene bank Platform)

Research and development of desirable traits will be crucial for accelerating the adoption of NUCs. Research centers will need a greater diversity of plant genetic resources to inhibit unwanted traits (e.g., disease susceptibility and anti-nutritional contents) and enhance useful (domestication) ones, such as early germination and growth, in well-designed breeding programs. The provision of improved NUCs seeds and increased efficiency in seed systems will pave the way to addressing several other NUCs production challenges hindering their adoption.

Production and processing technology and value addition

Apart from improved and high-quality seeds, which were discussed in the previous subsection, many NUCs systems are also lagging behind in terms of the adoption of other production and processing technologies, which hinders the development of efficient local, regional, and international value chains. Harvest and post-harvest technologies are 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 (FAO, 2024c; Mudau et al., 2022).

The harvest and post-harvest handling of many NUCs still involves time-consuming and manual practices, giving rise to significant product loss and a decline in quality. For instance, fonio millets are predominantly harvested using sickles and processed using mortar and pestle. The small size of the fonio grain makes it difficult to separate it from the chaff, with the traditional threshing and dehusking requiring tedious washing of the grain in water to remove the residual sand (Alercia, 2013; Farooq and Siddique, 2023). Although there has been progress in manufacturing time-saving and quality-enhancing processing machines, such as the Sanoussi Fonio machine and the GMBF (Guinea, Mali, Burkina Faso, France) huller, machine prices remain restrictive and ownership is almost exclusively achieved through collective acquisition by farmer groups or downstream organizations (Cruz et al., 2016; WFP, 2024b).

Cassava is another crop whose development is stalled by supply chain inefficiencies, which fuels its neglect and underutilization in many African countries. Cassava is a staple crop in many of the more than 100 countries where it is produced; it is consumed by over 800 million people globally (FAO, 2019). However, it has been considered a poor people’s staple for many years (Crop Trust, 2024b) and is still neglected and underutilized in several African countries, where more than 50 percent of the crop is lost to viral diseases (FAO, 2019). More than half of the global cassava supply originates from Africa, where production is characterized by intensive labor requirements and low yields, recorded at

7-9 tons per hectare, only one-third of the average yields in Asia and Latin America (AATF, 2024b). Since 2013, AATF's Cassava Mechanization and Agro-processing Project (CAMAP) has worked on promoting the cassava subsector through capacity building, enabling access to improved cassava stems, mechanization, and other farm inputs, and establishing market linkages with cassava processors in Nigeria, Uganda, Zambia, and Tanzania. In those areas, the project has increased cassava yields by 200 percent (from 7-9 tons up to 25 tons per hectare) and farmers' incomes by 100 percent, reduced drudgery for farmers, especially women, and boosted the appeal of cassava farming to many women and youths (AATF, 2024b). Although these impacts remain limited in geographical scale, they highlight that investments in the mechanization of production and processing of NUCs can be crucial for increasing their role in Africa's agrifood systems.

Some NUCs also require long processing time and removal of their anti-nutritional factors (ANFs), hindering their appeal to producers and consumers. ANFs are plant chemicals that interfere with the digestion, absorption, and utilization of nutrients by binding to them. When consumed in large amounts, these substances can negatively impact health. ANFs include tannins and lectins, which inhibit protein digestion, phytates, which limit mineral absorption, and many others, such as antivitamins and mycotoxins (Ali and Bhattacharjee, 2023). Some of those ANFs have been reported to be present in NUCs, such as Lima bean, fonio, and Bambara groundnut. The Lima bean contains phytates, protease inhibitors, which reduce the digestion of protein, and oxalates, which stimulate the formation of kidney stones (Adebo, 2023). Moreover, Bambara groundnut is known to require extra-long cooking hours, often more than four hours, until the content of ANFs is reduced, due to a hard seed coat (Farooq and Siddique, 2023; Majola, 2021). In addition, the phytate content in fonio is known to decrease the bioavailability of certain nutrients, such as iron and zinc (Koreissi-Dembélé et al., 2013). ANFs can only be reduced or eliminated using appropriate processing methods, such as fermentation, dehulling, cooking, and soaking (Ali and Bhattacharjee, 2023; Adebo, 2023).

Enhancing the utilization of modern value-addition technologies is crucial to deal with the competitive pressure from commercial crop alternatives of NUCs. This will require improvements in infrastructure and a supportive enabling environment, the lack of which is constraining the market penetration and economic viability of NUCs, and reducing their appeal among African farmers.

Infrastructure, market access, and economic viability

Infrastructural underdevelopment and limited input, output, and financial markets remain some of the key factors hindering the commercialization of agricultural products in Africa (Woldemichael et al., 2017; Hodder and Migwalla, 2023). These issues are more pronounced in the NUCs subsector, influencing African farmers to opt for other crops with greater commercial value.

Scarce investments in infrastructure hinder the development and adoption of NUCS in several ways. Along the NUCs value chains, there are inadequate stations for crop breeding, genetic improvement, and seed multiplication, as well as poor transportation, storage, and processing facilities (Farooq and Siddique, 2023; Senyolo et al., 2018; Tadele, 2019), which compel NUCs producers to rely on traditional and inefficient farm and product management practices. This, in turn, impedes the commercialization and market access of NUCs. For instance, despite the growing demand for nutritious NUCs, such as kale (Ngigi et al., 2011), amaranth, African eggplant, waterleaf, cocoyam (Asase and Kumordzie, 2018), and fonio (Lipton, 2024), inadequate transport and storage facilities in rural areas limit the potential for their large-scale production (Glatzel et al., 2024). Additionally, lack of organizational structures and market information adversely affects the enthusiasm for production and commercialization of NUCs such as African indigenous vegetables (Yu et al., 2024).

NUCs also face fierce market competition from mainstream staple crops (e.g., maize, rice, and wheat) across Africa, which has adversely impacted NUCs' economic viability and market access, leading to greater concerns about the profitability of their cultivation. Over time, this trend has led to lower demand and weaker marketing channels for NUCs, which has eventually caused the crop production area share of NUCs in Africa to significantly dwindle (Laborde et al., 2023). For instance, FAOSTAT data show that by 2020, the share of fonio, millet species, and sorghum in the total cereal production area had fallen to around 10 percent, compared to around 50 percent in 1960.

Moreover, unlike mainstream staple crops, whose demand and consumption are relatively stable during similar crop seasons, the markets for NUCs are often characterized by a series of boom and bust cycles, which hinders their long-term economic viability and market access. This has been the case for quinoa in Latin America and teff in Ethiopia during the past few decades (Andreotti et al., 2022). For instance, following teff's global demand boom in the 2000s, the Ethiopian government had to ban its exports between 2006 and 2015 (CNN, 2015; The Guardian, 2016) because the international market offered premium prices significantly higher than local prices, adversely affecting local teff supply. This discrepancy can negatively affect local producers when their production capacities are limited. The improvement of farmers' production capacities is crucial for boosting production efficiency and NUCs supply, which are key drivers of effective commercialization.

To overcome the market competition and commercialization challenges, a comprehensive value chain development will be crucial, starting with the improvement of seed systems and addressing infrastructural barriers to adoption. At the same time, tackling institutional and knowledge gaps that limit farmers' production capacity is vital to increasing the uptake of NUCs.

Institutional and knowledge gaps

The declining role of NUCs in African agricultural systems can also be attributed to policy and institutional support constraints. Inadequate support from governments and institutions can limit funding, training, and resources needed for the successful adoption of NUCs by farmers. The prevailing agricultural policies in Africa are biased towards commercial crops (e.g., maize, rice, and wheat), with little to no focus on their local traditional alternatives (Mabhaudhi et al., 2017; Padulosi, 2017; Papoola et al., 2023). For instance, the biased 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 NUCs (El Bilali et al. 2024). However, this is a result of competing policy priorities, as African governments have a higher incentive to invest more in crops with higher production potential and market demand to address persistent food insecurity.

This national policy orientation towards mainstream crops has meant that a major part of NUCs promotion is assumed by private initiatives and international organizations and donor programs. For instance, amidst the rising neglect and underutilization of millets worldwide, FAO declared 2023 as the international year of millets to raise awareness about their nutritional and environmental benefits. With their collaborators, FAO organized more than 100 awareness campaigns in around 35 countries to promote the production and consumption of millets, and engaged numerous stakeholders to enhance the integration of millet smallholder farmers into local, regional, and international value chains (FAO, 2024d). Additionally, a collaboration between the fonio machine company and the World Food Program has contributed to the introduction of fonio in school meals and the distribution of fonio machines among women- and youth-led farmer organizations in West Africa (WFP, 2024a). This has filled the policy gap and shows that public-private partnerships have a significant role to play in the promotion of NUCs. In collaboration with AATF, many governments are developing policies to improve their seed systems and regulatory framework to increase efficiency in seed delivery, access, and utilization. There is also an increasing collaboration between governments, CGIAR research centers, and private organizations, such as in The African Orphan Crops Consortium (AOCC), to leverage conservation and breeding technologies and expedite the delivery of improved seeds. Going forward, these collaborations and policy dialogues should incorporate NUCs in their portfolios to maximize their potential for addressing global nutritional, climatic, and biodiversity challenges.

Moreover, insufficient knowledge of and training on the availability and utilization of NUCs remain widespread across Africa, impeding their adoption. Limited knowledge of appropriate seed conservation hinders the seed viability of many NUCs, especially neglected vegetables. These include bitter leaf, African lettuce, jute mallow, okra, African eggplant, and blackjack, whose genetic resources are also scarce across various gene banks (N'Danikou et al., 2024). This results in a perpetual decline in the planting materials of NUCs, increasing the production risks among farmers who can hardly afford the price of improved seeds. In addition to the limited R&D investments in NUCS, some improved varieties that are released take a long time before they can be adopted due to low awareness among the intended beneficiaries. According to Oluoch (2024), improved seed development should be accompanied by promotion campaigns, such as on-farm demonstrations and field days to stimulate demand among farmers. This has been the case after the release of an improved pigeon pea variety in Kenya. Mainstreaming such outreach efforts for all available and forthcoming improved NUCs varieties can enhance and accelerate their uptake. Similar to quality seed promotion efforts, extension services, and interdisciplinary knowledge exchange are essential to increase the uptake and productivity of NUCs. Some NUCs, such as Kersting's groundnut, a neglected legume crop endemic to West Africa, have experienced a massive production decline due to poor crop management practices and scarce extension services to improve such practices (Farooq and Siddique, 2023). The legume's decline has also been attributed to the lack of organized efforts among stakeholders to develop its demand-led cultivars. Overcoming such knowledge gaps and the associated institutional constraints is essential in increasing farmers' and consumers' awareness of the benefits of NUCs, which could significantly increase their rate of adoption.

Overall, this subsection has shown that NUCs production in Africa is constrained by many factors, mainly seed availability, research and development, scarce production and processing technologies, infrastructural and institutional inefficiencies, policy biases, and limited production knowledge and capacities among NUCs producers. These challenges tend to coexist in several regions, and their interactions are increasingly being influenced by changing local and international consumption patterns. Accounting for demand-side challenges needs to be an indispensable part of the initiatives and interventions aiming to foster the uptake of NUCs in Africa and elsewhere.

3.2. Social behavioral change (SBC) strategies to increase NUCs adoption

Within the context of rapidly transforming agrifood systems and the need to consume healthier and more sustainable diets, NUCs have emerged as a central vehicle in delivering stable and nutritious diets in the face of climate variability and extreme weather events (Karl et al., 2024). The preceding sections have discussed the opportunities and benefits of adopting NUCs for nutrition and climate resilience and highlighted some key barriers to uptake. One central barrier to the uptake of NUCs at production and consumption levels is related to the adaptation of markets and consumer behavior (GAIN, 2024) and the perceived (un)attractiveness of a certain food product or specific crop.

The literature on changing food environments refers to this as the "desirability" dimension, alongside other factors driving food choices, such as affordability, accessibility, and convenience (Herforth et al., 2015; Turner et al., 2018). Even when target foods (such as 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. The same challenge applies when seeking to bolster the integration of NUCs in production and diets.

Yet, influencing the desirability and hence increased adoption and consumption of NUCs requires carefully-crafted interventions, anchored within behavioral change approaches. Nutrition SBC can play an important role in leveraging enablers of behaviours and reducing barriers to adopting and maintaining behaviors over time. Nutrition SBC is defined as a "set of interventions that systematically combines elements of interpersonal communication, social change and community mobilization activities, mass media, and advocacy to support individuals, families, communities, institutions, and countries in adopting and maintaining high-impact nutrition-specific and nutrition-sensitive behaviors and practices" (USAID, 2014).

The impact of behavior on nutrition outcomes

UNICEF has identified three main underlying causes of undernutrition, including inadequate care and feeding practice; household food insecurity; and unhealthy household food environments linked to matters of food safety and hygiene and inadequate healthcare services. The most immediate and underlying causes of malnutrition are behavioral, shaped by the actions of individuals and their family members. However, nutrition is also affected by the behaviors of various other stakeholders, including healthcare providers, educators, farmers, community leaders, private sector companies, and policymakers, all of whom play a role in influencing care and feeding practices, household food security, the home environment, and access to healthcare services. Interventions that address the underlying conditions and related behaviors as well as the enabling environment are considered nutrition-*sensitive*; while nutrition-*specific* interventions address immediate causes and behaviors that impact adequate dietary intake and low disease burden.

How to change and maintain new nutrition behaviors

To implement effective behavioral change interventions, it is essential to understand how individuals adopt behaviors and make decisions—in other words, to understand why individuals act the way they do. People typically operate within the contexts of their communities, families, and nations. In terms of nutrition, individual behaviors are shaped both directly and indirectly by social and economic environments, physical surroundings, food markets, and public and private services and policies that influence dietary choices. The socio-ecological model (SEM), often used to highlight the complexities of nutrition-related decision-making, is particularly relevant to SBC.

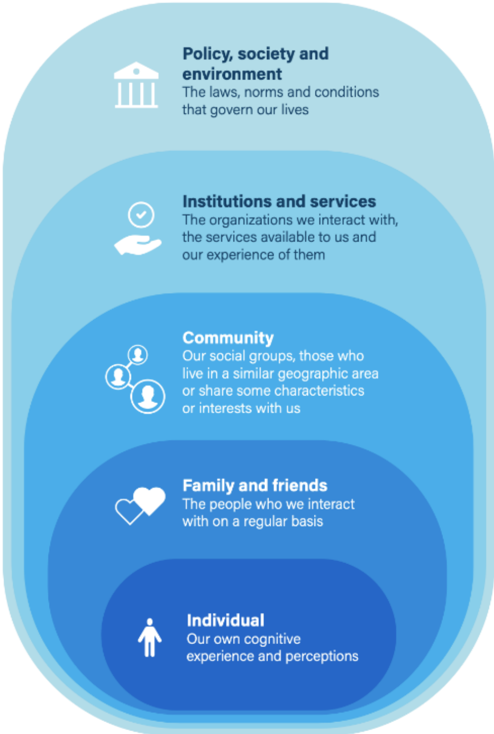

Figure 2: The socio-ecological model (SEM)

Source: UNICEF

The SEM demonstrates how effective SBC interventions can simultaneously transform social, physical, market, and policy environments, enabling individuals to adopt and maintain desired behaviors. Given the variety of influencing factors, it is crucial to promote behaviors through multiple strategies simultaneously, targeting different influencers and utilizing various points of contact, such as family members, peers, teachers, and healthcare workers.

At the same time, evidence suggests that for adopting and maintaining a given behavior, access to information alone is not enough (World Bank, 2015). To have the agency and willingness to act, individuals require access, motivation, encouragement, confidence, and support. However, while the SEM outlines the broader structures that influence behavior change, it does not include the cognitive and social mechanisms that influence behavior and the specific theories that can be used to drive change (UNICEF, 2023). Within the context of NUCs, a shift in social norms and traditions may also be needed as certain food groups or dishes are deeply anchored in cultural traditions and history – emotions are a further, often overlooked factor driving food choices (GAIN, 2024). This must be coupled with interventions that disrupt current eating habits and nudge individuals to trigger a different – desired – behavior. According to behavioral economics, individuals are more likely to adopt behaviors that align with their current mindset or mood. For example, attending a conference with a lunch buffet might encourage someone to try dishes they wouldn't typically prepare at home. Similarly, a farmer may be more willing to experiment with new seeds or fertilizers after experiencing a successful harvest.

A scoping study has identified over 82 models of behavior change, focusing solely on the individual (Davis et al., 2015). Other behavioral models and theories focus on community-level dynamics and examine the role of social norms and social networks. One model that is commonly used, for example by UNICEF, is the behavioral drivers model (BDM) (Petit, 2019). The BDM aggregates many different models and distinguishes between three distinct levers for influencing behavior:

- **Psychological** - the demographic and social characteristics that make people unique. This includes the beliefs, intentions, perceptions, and biases that influence decision-making.
- **Social** - the notion that people are never fully autonomous and are affected by social influence and norms. People are heavily influenced by and concerned about the opinions and actions of others. Positive and negative social norms can play a huge role in personal decision-making.
- **Environmental** - what people hear in public and private discourse can reinforce or challenge what they think. New and emerging viewpoints can be catalysts for alternative ideas. Public policies and services can also encourage or discourage certain choices.

In the context of nutrition SBC and more specifically, applying SBC techniques to nudge the adoption of NUCs, it is important to emphasize that different SBC interventions work well for different cultures and socioeconomic or age groups. Therefore, SBC interventions and messages must be designed in such a way that the right message for the right person is delivered at the right time (USAID, 2014).

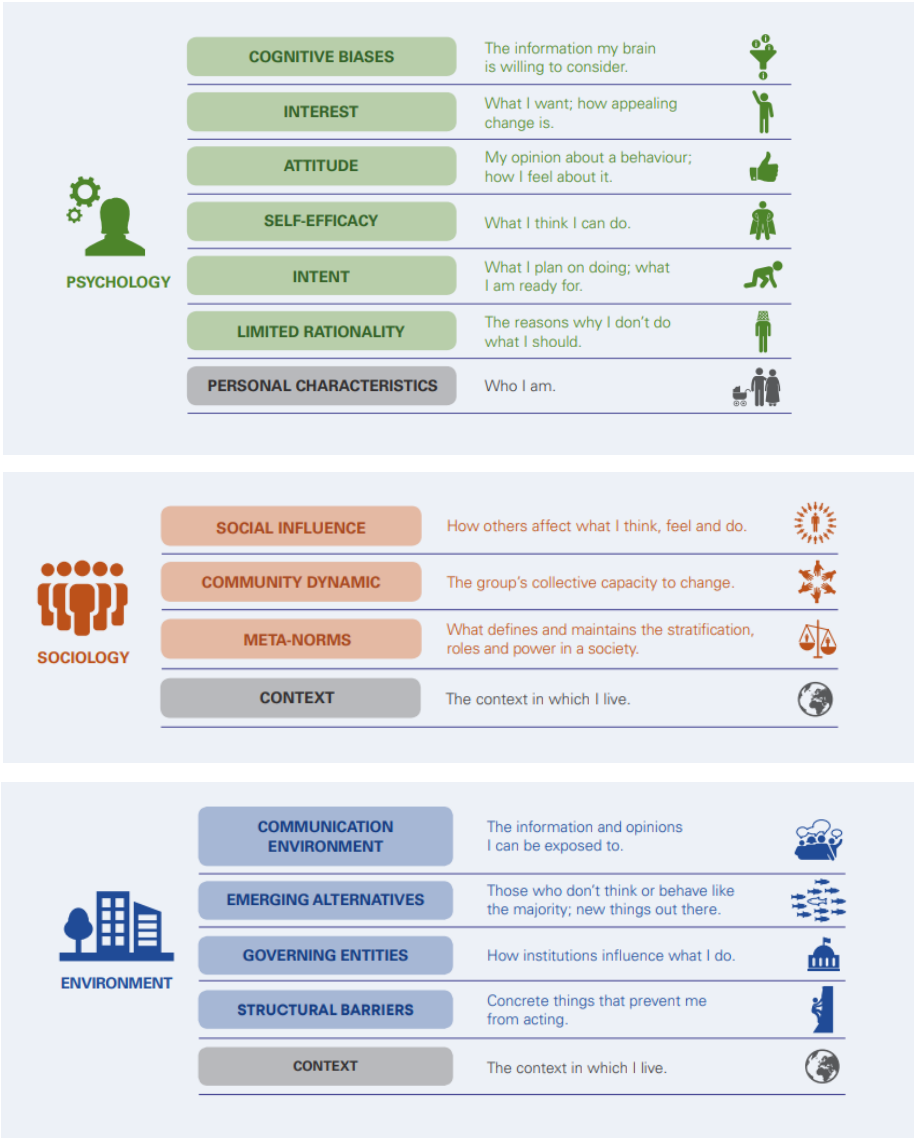

Figure 3: Main behavioral factors and levers

Source: Adapted from Petit (2019)

Examples of nutrition SBC interventions

SBC interventions have effectively shaped consumer behaviors regarding the consumption of healthy foods like fruits, vegetables, whole grains, and certain animal products, while also enhancing dietary diversity. However, the results of these interventions in addressing the intake of unhealthy foods, such as ultra-processed products and sugary drinks, have been mixed and are likely linked to the, at times, aggressive marketing campaigns of the food industry.

SBC interventions leverage informational, technological, and social platforms (for example, counselling or education, mobile phones, mass media, social groups, or gatherings) to apply common behavior change techniques, including:

- Providing instructions on how to perform a behavior (such as brochures or recipe cards), demonstrating a behavior (such as cooking or feeding sessions),
- Providing information on benefits or consequences (such as posters or TV/radio spots),
- Using a credible or influential source (such as campaigns with celebrities or community leaders),
- Adding objects to the environment or substituting with alternatives (such as food supplements or kitchen products), or
- Restructuring the physical or social environment (such as modifying physical spaces to make behavior easier, engaging groups that are not typically included, or mobilizing communities) (IFPRI, 2024).

The following paragraphs provide an overview of some successful SBC interventions in the nutrition and health sectors from which important lessons can be derived for generating demand for NUCs.

The most known “success story” of a NUC is likely that of quinoa as well as teff. Over the past 40 years, quinoa production has significantly expanded worldwide, particularly following its promotion during the UN International Year of Quinoa (IYQ) in 2013. This initiative aimed at highlighting quinoa's nutritional benefits and its role in food security. While the FAO collaborates with governments to protect quinoa biodiversity, key decisions regarding seed and genetic resource regulations are made at the national level. Quinoa's global popularity began in the 1950s due to rising demand from North America and Europe, leading to an increase in producer countries from seven in the Andean region to over 50 by 2013. Today, quinoa is cultivated in more than 123 countries across various climates. Historically regarded as a staple for local consumption in the Andes, quinoa has now entered the diets of urban populations in the US, Europe, and Asia, where a variety of quinoa products are widely available. This shift is partly attributed to the recognition gained from the IYQ-2013, positioning quinoa within niche markets like nutraceuticals, organic, and fair trade. Following the IYQ 2013, 26 countries, the majority in Africa, received FAO technical assistance to strengthen food security by promoting quinoa cultivation (Andreotti et al., 2022). Further details of the quinoa boom are provided in Box 7.

The designation of teff as a “superfood” due to its extensive nutritional benefits and its gluten-free nature led to increased global demand. Teff is a fine-grain cereal, believed to have been domesticated in Ethiopia around 3,000 years ago. Ethiopia is home to approximately 4,000 identified teff varieties, which are categorized into three main classes: white, red, and mixed (brown and white). Unlike quinoa, which gained international prominence later, teff has long been a staple food in Ethiopia, providing sustenance for 60–75 percent of the population. It occupies 28.5 percent of the country's cereal cultivation area and accounts for about a quarter of total cereal production. Teff is not only nutritionally valuable but also serves as a significant cash crop, with 36 percent of its production sold in local and global markets, often fetching higher prices than coffee. Traditionally, teff is used to make injera, a thin, sour pancake that is a staple in Ethiopian meals, along with other foods like porridge and unleavened bread. The teff grain plays an essential role in Ethiopia's social, economic, cultural, and political functioning and stability (Andreotti et al., 2022).

Despite being almost exclusively grown in Ethiopia and Eritrea, the demand for teff in high-income countries has recently soared because of its gluten-free nature and its nutritional value (Farooq & Siddique, 2023; Massawe et al., 2016). Because of unprecedented international demand, the Ethiopian government had to ban the export of raw teff between 2006 and 2015, the only exception being injera (CNN, 2015; The Guardian, 2016). After the ban, daily exports of injera bread to the United States alone were reported to have reached a record number of around 30,000 pieces (around 3 tons) (Daily Sabah, 2017). The latest data show that global injera exports from Ethiopia in the fourth quarter of 2023 were around 2,500 tons (ESS, 2024). In addition, teff has garnered increasing popularity in the European Union, where its imports rose from 524 tons in 2015 to 1,174 tons in 2019 (CBI, 2020). The CBI report emphasizes that following the revocation of a teff patent in the Netherlands and Germany in 2018 and its expiry across the EU in 2024, imports are expected to rise. This rise is mostly expected among European and North American flour milling, food processing, bakery, and beverage sectors, supermarkets, and health food shops catering to diverse consumers, especially diabetics, gluten-intolerant people, and athletes. These consumers are increasingly demanding nutrient-dense and gluten-free whole grains that are not genetically modified (CBI, 2020; Lee, 2019; The Teff Company, 2024). This rising demand presents a huge opportunity for teff farmers, especially those in Ethiopia, where more than 90 percent of global teff is produced by around 6.8 million farmers (Daily Sabah, 2017; Fikadu and Gebre, 2024).

Regional strategies, such as the Southern African Development Community (SADC) Social and Behavior Change Communication (SBCC) Strategy for Infant and Young Child Feeding in SADC Member States (2021-26), provide a good opportunity for anchoring and aligning NUC-specific SBC interventions. Crucially, integrating SBC into existing interventions aimed at improving nutrition outcomes is essential for enhancing the impact of multisectoral efforts aimed at fostering demand for healthy diets and the uptake of NUCs. This integration addresses supply challenges that restrict food options, such as availability and cost. Examples of these initiatives include nutrition-sensitive agriculture programs like home gardening and social protection programs that offer cash or in-kind support. These strategies can significantly boost dietary diversity and increase the consumption of micronutrient-rich foods, particularly benefiting women and children (IFPRI, 2024).

Box 7: Lessons from the quinoa boom in Bolivia and Peru

Between 2005 and 2014, quinoa exports from the world's leading quinoa-producing countries, Peru and Bolivia, increased seven-fold. During this period, quinoa prices in Peru surged by 500-600 percent, while production nearly quadrupled from 32,590 to 114,725 tons.

Long denigrated in South America as an "Indian food" for poor people, quinoa was largely unknown beyond the Andean highlands before it transformed into a "fashion food" and "super grain" across consumer markets in the US, Europe, and Asia. The peak was reached between 2011 and 2014 which particularly benefitted small farmers in the Andean highlands, many of whom had previously been unable to cultivate lucrative cash crops, leaving them to grow a handful of mostly native crops adapted to the environment, such as quinoa, kañiwa, oca, potatoes, and ulloco. These highland crops have historically fetched low prices, yet remained important parts of local production and diets. While small-scale farmers sold half a kilogram of quinoa for less than USD 0.25 in 2000, prices rose to about USD 4 during the "quinoa boom".

In 2013 and 2014, quinoa's rising market appeal prompted large-scale farmers along Peru's coast to shift from traditional crops like rice and asparagus to quinoa. This transition led to a dramatic increase in national production, with coastal output surging from 1,603 tons to 45,270 tons and overall production jumping from 44,046 tons to 114,342 tons. However, the influx of new quinoa producers in Bolivia and Peru contrasted sharply with the practices of traditional small-scale highland farmers. The large, market-oriented producers had access to finance and technology, which enabled them to enter volatile markets, reduce labor costs, and achieve higher yields. Moreover, they were located in low-altitude areas better suited to capital-intensive agriculture.

The UN's designation of 2013 as the International Year of Quinoa, accompanied by global promotional events further spurred this growth, encouraging both the consumption and production of quinoa worldwide. As a result, commercial quinoa farming began in Italy, India, and China, while the US and Canada expanded their previously small-scale experimental efforts.

The dominance of Andean small farmers, who had traditionally controlled quinoa production, was severely undermined by this large international supply increase. Unable to compete with better-funded and equipped large-scale producers at home and abroad, many smallholders were pushed out of the market. For example, large-scale farmers in Peru's coastal region, with two harvests per year, could yield 6,000 kg per hectare, while highland farmers were only able to produce 700 to 1,100 kg per hectare annually.

Despite quinoa's increasing global popularity, production outpaced demand, leading to a sharp drop in prices eventually. Since 2014, the price of quinoa has fallen by 75 percent.

3.3. Examples of country-level initiatives, policies, and strategies

Although community-level seed initiatives have existed for many decades, until recently they have received little attention in the contribution to climate change adaptation and plant genetic resources as well as improving nutrition outcomes and the uptake of NUCs. However, studies and examples from Africa suggest that community seed banks can enhance the resilience of farmers, by providing improved access to, and availability of, diverse, locally adapted crops and varieties, and enhancing related indigenous knowledge and skills in plant management and nutrition (Vernooy et al., 2017).

Kiziba Community Seed Bank, Uganda. Established in 2008, the Kiziba community seed bank in Southwestern Uganda serves as a model for conserving crop diversity at the community level, enhancing the quality and accessibility of the seeds that local farmers prefer, focusing on common bean and banana. The seed bank serves over 1,000 farmers with 70 varieties of bean seeds. The community initially had 13 varieties of beans, the other varieties were introduced from other communities in the country and some were provided by the national gene bank.

Seed Savers Network, Kenya. The Seed Savers Network aims at revitalizing indigenous seed-saving practices and biodiversity conservation by mobilizing farmers. It identifies experienced senior farmers who utilize traditional knowledge and local varieties, encouraging them to share their expertise with others. Farmers' groups are trained in seed selection techniques to enhance existing varieties, and each group establishes a seed bank at the end of the growing season. The second objective focuses on improving seed supply in villages, particularly for crops like fruit tree seedlings, cassava cuttings, and local vegetables. The 35,000 farmers that are subscribed to the Network are organized into seed banks to maintain crop quality and provide seeds as needed. Custodian farmers who supply vegetatively propagated crops are added to a database to help connect supply with demand. The network also conducts annual training-of-trainers courses covering seed sovereignty, laws, production, and processing. Seed fairs are organized to facilitate seed sharing and exchange among farmers, inviting public and private sector stakeholders. To document local varieties and indigenous knowledge, the Seed Savers Network uses a community biodiversity register. This information is shared with a broader audience through social media and local radio programs.

African Orphan Crops Consortium (AOCC). AOCC has the greater integration of orphan crops into African food systems at its heart. To support this, its goal is to sequence, assemble and annotate the genomes of 101 traditional African food crops, to facilitate 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. This initiative dubbed the African Plant Breeding Academy, led by UC Davis, draws on an international team of instructors from both the public and private sectors. Nutrition is at the core of the AOCC, intending to make NUCs more productive and more profitable for African farmers to grow, and easier for consumers to use.

BOLD Project, Crop Trust. Launched in 2021, BOLD (Biodiversity for Opportunities, Livelihoods, and Development) is a 10-year project to strengthen food and nutrition security worldwide by supporting the conservation and use of crop diversity. 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 component “BOLDER” (Building Opportunities for Lesser-known Diversity in Edible Resources). Working with partners in Benin, Ghana, Tanzania, and Uganda, BOLD seeks to enhance the conservation, production, and consumption of lesser-known crops that are nutritious, robust, environment-friendly, and important for local communities. Recognizing the importance of stimulating demand to achieve the desired impact on nutrition outcomes, the project will work with experts in agricultural value chains in partner countries to increase the cultivation and production, improving the availability, production, and consumption of nutritious food for both rural and urban consumers, and creating employment and income opportunities for youths, women, and indigenous communities. BOLDER is also part of the VACS initiative.

4. Country case studies

4.1. Cameroon

Cameroon achieved lower-middle-income status in 2008 and experienced modest economic growth, averaging 4.3 percent annually from 2010 to 2019. However, growth slowed due to the COVID-19 pandemic and subsequent economic shocks (World Bank, 2022). The economy is largely driven by agriculture, oil, and services. Agriculture’s contribution to GDP has ranged between 16.5 and 18.5 percent over the past two decades, employing more than 50 percent of the labor force, predominantly in rural areas (AGRA, 2024; IFAD, 2024a; WB, 2024). Cameroon’s agricultural sector is critical for food security and exports but remains vulnerable to climate risks such as erratic rainfall and soil degradation. To address these challenges, Cameroon adopted Vision 2035, aiming to transform the country into a middle-income economy through improving infrastructure, promoting sustainable agriculture, and addressing poverty and malnutrition by 2035 (MINEPAT, 2009). Achieving Vision 2035 goals will require effective strategies that expand Cameroon’s narrow production base, tap the potential of its abundant water, forest, mineral, and energy resources (AfDB, 2023), and embrace transformative approaches that will empower millions of poor farmers to efficiently produce more food, including NUCs. The government and its partners have successfully increased the importance of crops like cassava and plantain in Cameroon’s agricultural system and economy, transforming them from neglected crops to major staples and commodities. These efforts should now be extended to other NUCs, such as neglected cereals, legumes, and vegetables.

Status of NUCs production and consumption

The diminishing role of agriculture in the economy, growing urbanization, and adverse weather conditions are significantly changing food production and consumption patterns in Cameroon. These changes are adversely affecting nutrition outcomes, and local NUCs, such as Bambara groundnut, millets, cocoyam, taro, cassava, and plantain can play a crucial role in improving nutritional outcomes (Karl et al., 2024; WB, 2019).

Promoting local NUCs in Cameroon can enhance diet diversity and improve the livelihoods of millions of smallholder farmers, who supply more than 80 percent of the food locally consumed (Mbiafeu et al 2024; Molua, 2006). The International Fund for Agricultural Development (IFAD) estimates that the current local food supply is primarily driven by approximately 2 million smallholder farms, supplemented by fewer agro-industrial plantations and large-scale private farms. Moreover, around 8 million rural Cameroonians rely on tropical forests, which cover about 40 percent of the country's surface area, for food, fuel, medicine, and construction materials (World Bank, 2022b). These food supply sources are fragile and increasingly vulnerable to climate hazards such as extreme temperatures, floods, and droughts. The World Bank estimates that climate risks affect around 9 percent of the population (roughly 2 million people in 2022), with the most vulnerable being the farming communities residing in Cameroon's Extreme-Nord, Nord, and Adamaoua regions. Greater uptake of local climate-resilient NUCs can improve resilience to climate challenges while tackling widespread malnutrition issues in the country, including undernutrition, high child stunting and anemia rates, and rising obesity across various age groups. According to recent FAO and Global Hunger Index data, Cameroon's prevalence of undernutrition is around 5.7 percent (roughly 1.6 million people) of the total population, and the prevalence of child stunting and wasting is 28.9 and 4.3 percent, respectively, as shown in Figure 4. In comparison, in 2000, 22.6 percent of the total population was undernourished, while 36.6 percent and 7.4 percent of children suffered from stunting and wasting, respectively. Additionally, today 41.2 percent of Cameroonian women of reproductive age suffer from anemia, while 10.5 percent of children aged below 5 and 14.4 percent of the adult population (aged 18 and above) suffer from obesity. In comparison, the prevalence of obesity in the adult population was around 6.8 percent in 2000. These contrasting malnutrition trends point to the changing food supply and consumption behaviors in the past few decades. Policies that encourage greater diversity in the food supply and consumption of nutritious diets are required to address these complex challenges. Furthermore, despite the observed decline in undernutrition in the total population, the high level of child stunting and anemia, and the rising prevalence of obesity point to the inadequacy in consumption of vital nutrients that are abundantly available in several NUCs adapted to the Cameroonian environmental conditions.

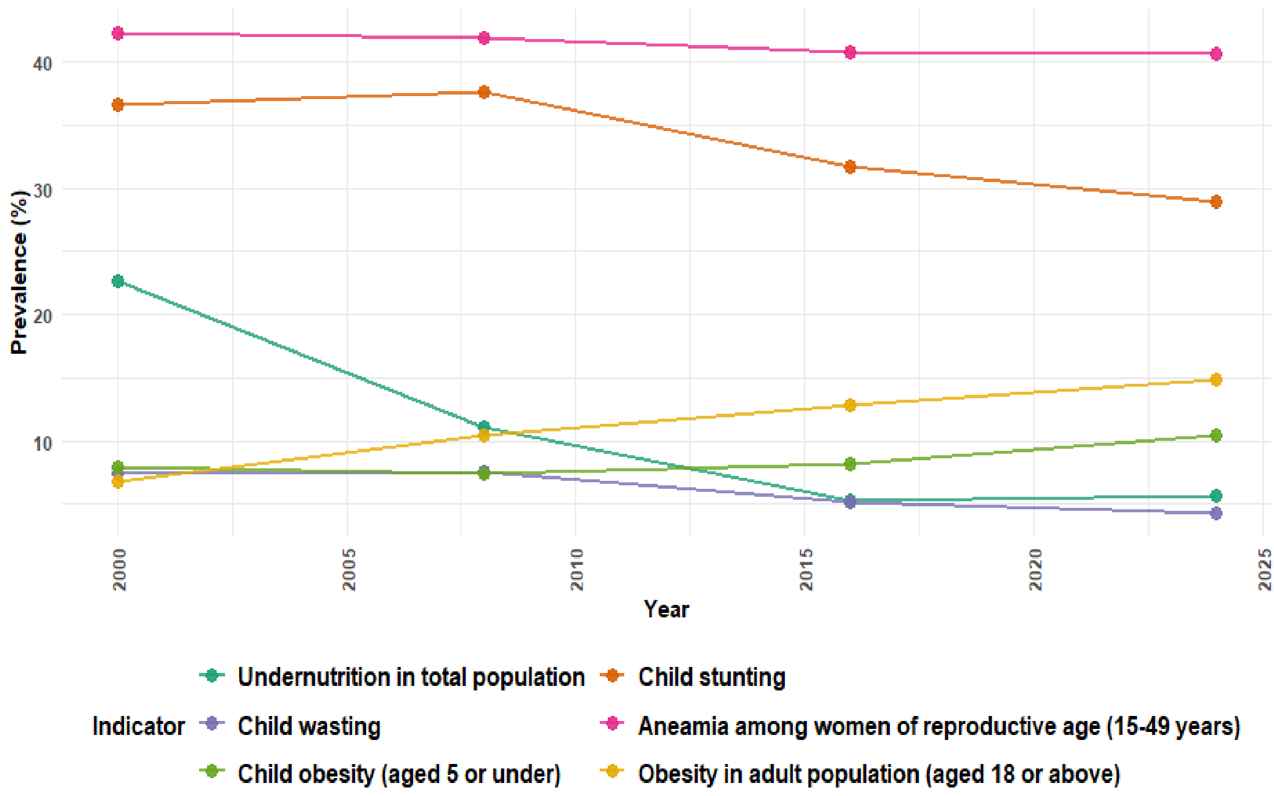

Figure 4: Evolution in nutrition indicators in Cameroon

Source: FAO (2024a) and Wiemers et al. (2024)

Several nutritious NUCs are produced and consumed in Cameroon, including cereals, legumes, vegetables, roots, and tubers. Some examples include Bambara groundnut, cocoyam, taro, cassava, okra, plantain, African eggplant, African yam bean, broad bean, Kersting's groundnut, jute, moringa, cucurbitaceous crops[5], millet, sorghum, and sweet potatoes (Achu et al., 2005; FAOSTAT, 2024; Farooq and Siddique, 2023; Karl et al., 2024; Tadele, 2019; Wanguili et al., 2021; WB, 2019). The evolution in the production area and quantity of some NUCs between 2000 and 2022 is shown in Figure 5. As can be seen, the production of plantain, sorghum, yam, and sweet potato dominates the NUCs subsector in Cameroon. The harvested area of all NUCs considered has experienced a modest increase during the past decades, while the production increase was very limited for most of them.

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[5] Cucurbits represent a family of pumpkins, squash, gourds, and similar crops. In addition, plantain, though considered a neglected crop in many countries, is a priority crop in Cameroon, and is added for comparison purposes.

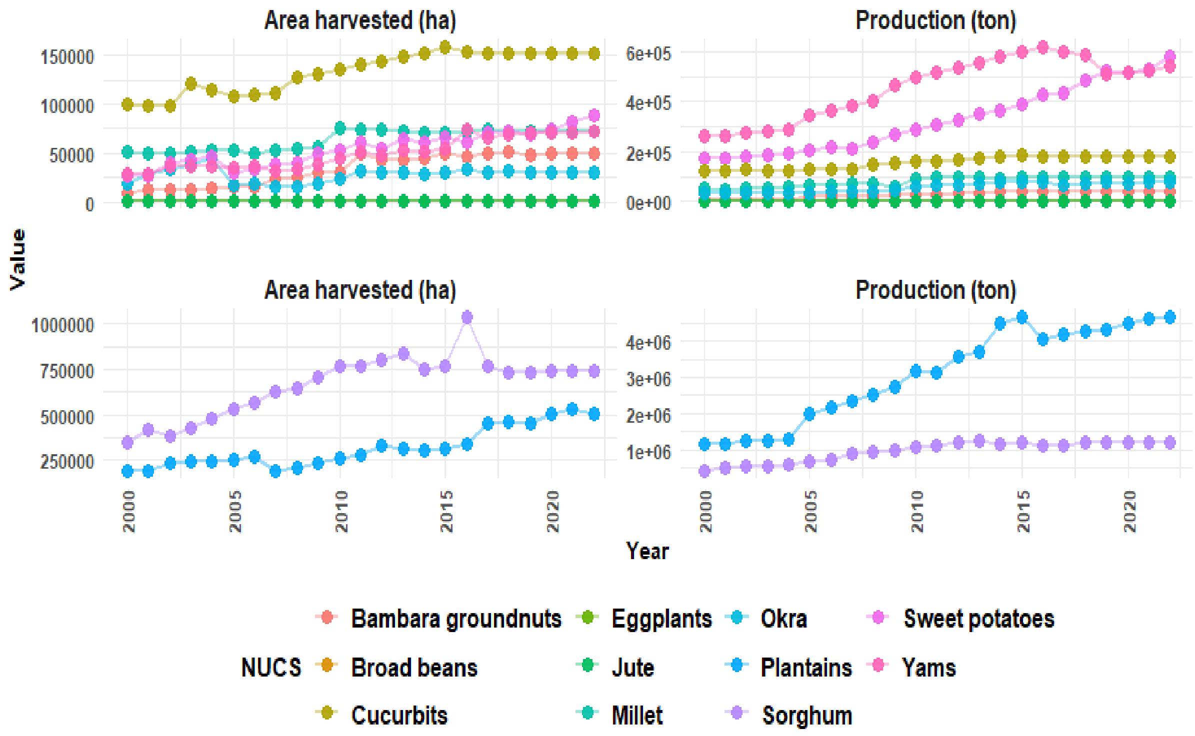

Figure 5: Evolution in selected NUCs production Cameroon

Source: FAOSTAT (2024)

Despite the rise in the harvested area of Bambara groundnuts, broad beans, eggplants, jute, millet, and okra, their production quantities have remained relatively stagnant for more than 20 years. Additionally, sorghum, cucurbits, and millets exhibit a significant disparity between harvested area trends and production quantities. Despite having the first, third, and fourth highest harvested areas, respectively, their production quantities remain among the lowest within the NUCs subsector. These trends suggest that Cameroonian farmers may be expanding their NUCs cropland to offset limited access to productivity-enhancing inputs and stagnant yields, driven by the growing population's increasing food demands.

The production of Bambara groundnuts in Cameroon has been neglected for several decades despite its nutrition, climate resilience, and nitrogen fixation benefits. The latest figures show that this legume's harvested areas experienced a negligible increase, and its total output experienced a similar trend to reach only around 50,000 tons in 2020 (FAOSTAT, 2024). Bambara groundnut is mainly grown on smallholdings using traditional landraces and indigenous production practices. A recent review by Temegne et al. (2020) showed that Bambara groundnut is mostly grown by women (around 78 percent of all growers), with 60 percent of all farmers growing the crop in monocultures and the remaining 40 percent intercropping it with other NUCs, such as okra, pumpkin, beans, tubers, millets, and sorghum (Temegne et al., 2020). There has been a scarcity in R&D for Bambara groundnut to improve its yield and resistance to biotic and abiotic stressors. Its hard seed coat and the presence of anti-nutritional factors also limit this crop's appeal to consumers (Farooq and Siddique, 2023; Majola, 2021). Addressing these challenges will be pivotal in boosting its uptake and harnessing its human and environmental benefits.

The local production of sorghum and different millet species also remains underdeveloped in Cameroon, notwithstanding their role in energy supply and their inclusion in numerous local staple diets, such as the popular traditional dish couscous. Recent USDA data show that three regions in the country account for 98 percent of millet production: Extreme-Nord, Nord, and Adamaoua regions produce 50 percent, 45 percent, and 3 percent, of total millets, respectively (USDA, 2024). The total nation supply of millets has stagnated at around 100,000 tons annually for more than a decade (FAOSTAT, 2024). Similarly, USDA data indicate that almost all of the sorghum production in Cameroon is distributed in Extreme-Nord, Nord, and Adamaoua. These regions account for 60 percent, 34 percent, and 6 percent of the national sorghum supply, respectively. Although sorghum's harvested area has more than doubled during the past two decades to reach 74,000 hectares, the highest level among all the recorded NUCs, its total output has stagnated at around 120,000 tons annually since 2012 (USDA, 2024). One possible explanation for this trend is that the three regions producing most of the sorghum and millets in Cameroon are the most vulnerable to weather shocks, such as extreme temperatures and droughts (WB, 2022). These crops' stagnant output levels in recent decades also indicate that they have received negligible R&D attention. Promoting climate resilience measures in the key production areas of these cereals will be crucial in realizing their full potential.

Cucurbits, such as gourd, squash, and melon, have great culinary importance in popular Cameroonian dishes like Egusi but remain neglected and underutilized. These crops are rich in several nutrients, such as proteins, lipids, and fiber. Achu et al. (2005), in their analysis of various cucurbitaceous species cultivated in the Sahel, High Savanna, Rain Forest, and Swamp Forest regions of Cameroon, revealed that these species are protein-rich, with protein content ranging from 28 to 40.5 percent in seeds and 61 to 73.6 percent in their defatted cakes. Additionally, they contain high lipid levels, similar to those found in other oilseeds. Their moisture, crude fiber, and ash content are also comparable to those of soybean, peanut, sesame, and sunflower seeds.

The production of sweet potato in Cameroon has experienced a steady rise for the past two decades. In 2022, sweet potato was the third-most produced crop behind plantain and sorghum in the NUCs subsector, accounting for 579,883 tons (FAOSTAT, 2024). Sweet potatoes are rich in nutrients, such as carbohydrates, vitamins, and minerals like iron, calcium, and phosphorus (CIP, 2024; The Borgen

Project, 2023). As Cameroon relies completely on imports for wheat supply, the frequent wheat price volatility in recent years has induced local businesses to adopt sweet potato flour as an alternative to wheat flour (The Borgen Project, 2023). The Borgen Project has reported that bakeries and biscuit factories in Yaoundé and Doula are increasingly switching from wheat flour to low-cost sweet potato flour sourced from local farmer cooperatives. This switch supports businesses in reducing production costs, stabilizing local bread prices, and promoting the cultivation of sweet potatoes. Furthermore, Nkongho et al. (2014) report a growing utilization of sweet potato leaves and stems in soup preparation in Cameroon. The increasing utilization of sweet potatoes is encouraging; however, greater efforts are needed to enhance its adoption among consumers and farmers to fully capitalize on its growing commercial value and productivity potential, even under adverse climatic conditions.

Yam is another neglected root crop with limited uptake in Cameroon. It is an energy crop, rich in starch and dietary fiber, with varying levels of protein, lipids, and minerals depending on the yam variety (Obidiegwu et al., 2020). It is a culinary versatile crop, which can be boiled, roasted, baked, or pounded to make fufu, and used to prepare soups and snacks such as fritters and chips (Azeteh et al., 2019). Cocoyam, one of the yam varieties, is a core ingredient for Ekwang, a popular Cameroonian dish (Preciouscore, 2020). However, these consumption benefits are scarcely exploited in Cameroon because of the prevailing production constraints. Yam's harvested area and production volume in Cameroon have increased over the past two decades, although recent data show a slight decline since 2020. Yam production peaked in 2016 at 618,135 tons, and has recorded lower numbers ever since, with the latest output amounting to 543,280 tons in 2022 (FAOSTAT, 2024). About nine domesticated and 17 wild yam varieties are cultivated by subsistence farmers across Cameroon's five agroecological zones (Azeteh et al., 2019). The review by Azeteh et al. (2019) reported several constraints limiting the adoption of yam in Cameroon. Despite being grown in the country for at least two centuries, yam has received limited research and policy attention, which has hindered its productivity and economic potential. Yam production remains labor-intensive and vulnerable to abiotic and biotic stressors, especially to pre- and post-harvest pests due to traditional crop management practices. Lastly, yam farmers depend on their harvests to preserve seeds for the next planting season, and there are no yam germplasm collections in local gene banks, limiting the potential for any yam breeding program. Greater R&D investments and an enabling environment will be crucial for addressing these challenges.

Expert interviews have also revealed several locally grown but neglected crops with high nutrition, climate resilience, and nutraceutical potential in Cameroon. These include the African pear, also known as African plum or bush butter, Chayote (*Sechium edulis*), fluted pumpkin (*Telfaira occidentalis*), Roselle (*Hibiscus sabdariffa*), Ethiopian eggplant (*Solanum aethiopicum*), scarlet eggplant (*solanum gilo*), black nightshade (*Solanum nigrum*), waterleaf (*Talinum triangulare*), jute mallow (*Corchorus *oliturus*), horn-fruited jute (*Corchorus tridens*), the African boabab (*Adansonia digitata*), and black jack (*Bidens pilosa*).

Enabling environment: Existing policies, regulations, and strategies

Increasing the adoption of NUCs in Cameroon will require a supportive enabling environment, where policies, regulations, and development strategies offer farmers incentives to expand production and raise consumer awareness about the nutritional benefits of NUCs. The existing conditions are limited in these areas, but several R&D and marketing interventions have successfully transformed some crops once considered NUCs into staples of wider use, playing a key role in addressing pressing sustainable development challenges in Cameroon. However, the country's seed system development is still in its infancy (AGRA et al., 2024), implying that unlocking the full potential of NUCs alongside other crops will require greater and concerted efforts from public and private actors.

Similar to many developing countries, Cameroon's agriculture sector is marked by a dominance of informal seed systems (AGRA et al., 2024; Tata et al., 2016). The national seed sector is still in its early development stages, with the government working alongside development partners to create a sustainable and efficient seed policy (AGRA et al., 2024; TAAT, 2024). Three government institutions, the Agricultural Research Institute (IRAD), the Ministry of Agriculture (MINADER), and the National Council for Seeds and Breeders' Rights (CONSOV) are responsible for seed sector development (AFD et al., 2018). Local seed supply is predominantly handled by private enterprises, including local and multinational companies, producer cooperatives, and individual producers (AGRA et al., 2024). The Access to Seed Index Report published in 2019 indicates that 13 seed companies were active in seed marketing in Cameroon, with only two (SEMAGRI and TECHNISEM) owning local breeding stations, and together with BAYER, only three providing extension services. In addition, some producer cooperatives have made notable contributions to seed supply, including those of NUCs. Some examples include CAPLABAM, which produces hybrid seeds for sorghum, and GIC Nguegoue, which produces potato seeds, with six varieties sold at local markets (AFD et al., 2018).

However, the seed sector in Cameroon has been characterized by ineffective performance during the past several years. The AGRA et al. (2024) Seed Sector Performance Index Report highlights many bottlenecks in Cameroon's current seed sector. The report indicates that the sector mainly focuses on four crops, maize, rice, cassava, and sorghum. The last two crops are considered NUCs in many African countries, and this focus indicates that they play a crucial role in Cameroonian agricultural systems. In 2022, the commercial seed supply of cassava amounted to 8,000,000 tons (17 percent of national seed requirement), and that of sorghum amounted to 179 tons (71 percent of national seed requirement)

(AGRA et al., 2024). Moreover, since 2018, there has been no release of new seed varieties of the four focus crops, and by 2022, there were only 14 cassava varieties, and 11 sorghum varieties used in cultivation. This is not specific to these crops, as there exists a widespread scarcity of crop genetic variety across local in-situ gene banks, including those managed by the Institute of Agricultural Research for Development (IRAD) and the National Forestry Development Agency. Limited human and financial resources also remain key constraints for seed sector development. For instance, IRAD, the leading national agricultural institute, only has three breeders, who all work on maize.

At the policy level, a recent MINADER report has outlined a series of legal instruments used to regulate Cameroon's seed sector, including:

- Law No. 2001/014 of 23 July 2001 relating to seed activities,
- Decree No. 2005/153 of May 4, 2005 on the creation, organization and functioning of the National Council for Seed and Plant Varieties,
- Decree No. 2005/3091/PM of 29 August 2005 to lay down the modalities for seed production, quality control and marketing,
- Decision No. 540 /MINADER/SG/DRCQ/SDRSQV of 7 September 2006 to approve the official technical regulations for the production, control, and certification of seeds of some cereals (composite maize, hybrid maize, rice, and open-pollinated sorghum).
- Joint Order No. 380/MINADER/MINCOMMERCE of 7 August 2006 laying down specifications for the production, import and marketing of seeds and seedlings,
- Order No. 00073/MINADER/SG/DRCQ/SDRSQV of 22 April 2019 laying down the procedures for the registration of species and varieties,
- Decision No. 1208 /MINADER/SG/DRCQ/SDRSQV of 25 August 2014 listing some species and varieties of economically important food crops (maize, rice, cowpea, soybean, bean, plantain, cassava, potato) in the official catalogue of species and varieties, and
- Decision No. 00652/MINADER/SG/DRCQ/SDRSQV of 1 December 2020 to approve and make enforceable the protocols of Distinctness, Uniformity and Stability (DUS) and Agronomic and Technological Value (VAT) tests for cowpeas (*Vigna unguiculata*.) before any new cowpea variety is registered in the Official Catalogue of Species and Varieties.

Certified crop species and varieties are listed in the official catalogue for a renewable period of five years. Currently, the catalogue contains a number of certified NUCs varieties, including five for Plantain, two for cowpea, three for sorghum, four for beans, six for cassava, two for okra, four for bush okra, three for amaranth, five for green bean, and 20 for cucurbits (MINADER, 2023).

The existing policy framework is narrow and ineffective, which contributes to the neglect and underutilization of several NUCs, especially traditional vegetables. It has been shown that 80 percent of traditional vegetable producers in Cameroon rely on informal seed systems, while producers of some neglected crops such as fluted pumpkin and bitter leaf rely 100 percent on their produce to preserve the seeds for future planting (Abang et al. 2014; Tata et al., 2016). Tata et al. (2016) report that IRAD has discontinued its vegetable seed production system due to a shortage of human and financial resources. They also indicate that formal vegetable seed systems are dominated by imported varieties because the local procedures for seed variety release are too bureaucratic and cumbersome, discouraging local actors from participation.

Nevertheless, a few R&D initiatives have contributed to the revival of once-neglected crops, which has turned them into staple crops in Cameroon. One such initiative is the African Center for Research on Banana and Plantain (CARBAP), which was established in 2001 and is headquartered in Cameroon. Its mission is to deliver improved varieties and production technologies to enhance the sustainable production capacity of bananas and plantains in West and Central Africa, where these staple crops remain underdeveloped. In addition, the CARBAP engages in several international research collaborations, such as with the French Agricultural Research and International Cooperation Organization (CIRAD) to enhance the exchange of knowledge and best practices. CARBAP contributes to the improvement of the productivity and competitiveness of the plantain and banana sectors in more than 10 countries, including Cameroon, Democratic Republic of Congo, Côte d'Ivoire, Ghana, Guinea, Gabon, Equatorial Guinea, Central African Republic, and Nigeria, among others. The Center maintains one of the largest cultivated field collections of banana genetic resources globally, comprising approximately 596 accessions, including 135 specifically for plantains (CARBAP, 2014). These efforts have led to the development of varieties resistant to abiotic and biotic stressors, such as the Fusarium Wilt Disease, contributing to higher productivity and incomes.

In addition to Cameroon’s favorable ecological conditions, the rise in R&D has propelled Cameroon to become the top producer of banana and plantain in Africa and it aims to become the world’s leading producer by 2030 (Xinhua, 2024). To meet the country's target of 10 million tons of annual production by 2030, up from the current 6 million tons, the government is investing in additional R&D programs to develop varieties resilient to climate change and plant parasites. Due to their high commercial value, efficient banana and plantain production has the potential to enhance household incomes and improve food security. Banana and plantain are rich in potassium and their consumption helps to regulate body metabolism, among other functional benefits (Dongyu, 2024). Given Cameroon’s conducive tropical environment, more investments in boosting banana and plantain production capacity could play a pivotal role in tackling malnutrition and poverty challenges across the country.

The Cameroonian government also has some plans and initiatives that cover the overall agriculture industry, with major implications for NUCs. For instance, Cameroon's Vision 2035 aims to transform the country's dominant subsistence farming sector into a modern, intensive, and mechanized agricultural sector by 2035 (MINEPAT, 2009). The government aims to increase agricultural mechanization from 1.5 tractors per 100 square kilometers (sq km) in 2010 to 30 tractors per 100 sq km by 2025, and further to 116.5 tractors per 100 sq km by 2035. The vision also aims to boost investments in agricultural R&D and irrigation, particularly in the drought-prone northern region, promote agro-industries, enhance environmental protection and climate change control, and improve rural financing to reduce the poverty rate to below 10 percent by 2035. Additionally, the government's industrialization drive aims to reduce the primary sector's share in total employment, from 49 percent in 2010 to 26.9 percent by 2035. This will mean fewer people involved in farming, requiring greater crop productivity to feed the growing population. However, most of the prevailing government and partner programs, including the 2020-2030 National Strategy for Transformation (MINEPAT, 2020), narrowly focus on a few key staples (maize, rice, plantain, cassava) and export crops (palm oil, cocoa, coffee, and cotton). Consequently, NUCs risk falling into further disuse if the government's development ambitions keep overlooking them.

Government and partner projects targeting NUCs

With around 47 percent of its labor force employed in agriculture (World Bank, 2019), Cameroon's sustainable development requires strategic partnerships to enhance agricultural productivity and address challenges like poverty, malnutrition, and climate change. Agricultural productivity growth is reported to be eleven times more effective at alleviating extreme poverty than economic growth in any other African industry (IFAD, 2017). To realize these benefits, the Cameroonian government has set ambitious medium- and long-term goals outlined in the Cameroon Vision 2035 and the National Development Strategy (SBD30) for 2020-2030. The government is collaborating with diverse stakeholders to boost agricultural productivity growth through different approaches, such as the development of a sustainable national seed system and the promotion of agricultural commercialization and agro-industrial activities (WB, 2019).

Cameroon's recent approach to agricultural development is consistent with the growing recognition that greater utilization of high-quality seeds is a key driver of agricultural productivity, food security, and income growth in many African countries (AGRA, 2024; TAAT, 2024). In this regard, the Cameroonian government is engaging in consultations with local, regional, and international research centers and other development stakeholders to draft seed roadmaps and strategic plans for its national seed systems. These discussions are made under the auspices of the Technologies for African

Agricultural Transformation (TAAT) Program, which was initiated by the African Development Bank (AfDB) in 2018. The Program's mission is to promote technology-driven productivity gains in major commercial commodities (e.g., maize, rice, wheat, livestock, and aquaculture), and some neglected crops, such as high-iron bean, cassava, orange-fleshed sweet potato, plantain, sorghum, and millets (AfDB, 2024; TAAT, 2024). To implement these changes, the government is collaborating with TAAT for seed industry assessments, agricultural policy dialogues, seed policy reforms, and accreditation of agro-input suppliers, among other things.

Another project that targeted NUCs was the Roots and Tubers (R&Ts) Market-Driven Development Program, which was co-financed by the government of Cameroon and IFAD and implemented from 2003 to 2012. This Program aimed to improve food security and smallholder livelihoods in rural areas, especially among vulnerable groups, such as women and the youth. It aimed at strengthening the R&T value chains, particularly for cassava, by offering technical support, capacity building for production and post-harvest handling, promoting producer organizations, and improving market development and access. It also emphasized fostering vertical integration among all industry players to improve efficiency and collaboration. The Program's value chain approach had a positive impact on crop productivity and improved the welfare of its beneficiaries. The initial plan included several R&Ts, such as taro, yam, sweet potato, and potato, but later focused on cassava only. The Program completion report[6] indicates that cassava yields in the intervention areas rose from 8-10 t/ha to up to 37 t/ha, which was more than twice the national average of 13-14 t/ha in 2010-11. In collaboration with local research institutes and the International Institute of Tropical Agriculture (IITA), the Program also increased farmers' access to improved plantation materials. In addition, there was an increase in the amount of cassava available for consumption from 122 kg/person to 194 kg/person, per year at the end of the Program. This enabled beneficiaries to allocate 30-40 percent of cassava production to household consumption and the remaining 60-70 percent to market-oriented processing. The Program also led to higher household incomes, with a 66% increase in gross margin, diversified household diets, and a reduction in child malnutrition in the intervention areas to 4.2 percent, compared to the national average of 7.5 percent in 2011. Overall, the Program benefited around 18,000 households, corresponding to roughly 108,000 individuals, of which 62.5 percent were women.

One additional government project that involved the promotion of NUCs in Cameroon was the Agriculture Investment and Market Development Project, which was co-financed by the World Bank. The project was implemented between 2014 and 2021 with the objective of supporting the transformation of low-productivity, subsistence-oriented cassava, maize, and sorghum subsectors into

[6] https://www.ifad.org/documents/48415603/49557858/Project+Completion+Digest+September+2014_12.pdf/ebfeaced-cc66-c984-a4c7-5a55d538d185?t=1726611298304

commercially oriented and competitive value chains in four agro-ecological areas (WB, 2022a). The World Bank's Project completion report indicates that cassava yields increased from 8 to 22.35 and sorghum yields from 1 to 1.91 tons per hectare among beneficiary farmers. This productivity gain is attributed to various project interventions, including the rehabilitation of 217 km of roads, the establishment of 115 post-harvest and processing facilities, and the delivery of labor-saving technologies (e.g., machinery) to 8,735 women. Furthermore, the increase in yields was driven by the production and distribution of foundation seeds, including 78 tons of sorghum seeds, 8,975,000 tons of cassava cuttings, and 385,000 tons of biofortified cassava cuttings. Additionally, certified seeds were produced and distributed, such as 137 tons of sorghum, 17,394,000 tons of cassava cuttings, and 169,500 tons of biofortified cassava cuttings in project areas. The Project also implemented a value-chain development approach centered on institutional innovation. This included establishing governance and accounting systems within 75 producer organizations, building the capacity of their members, and registering these organizations as cooperatives. Additionally, the Project initiated a commodity-based public-private consultation and partnership framework, facilitating 20 productive partnership agreements, including those with financial institutions. As a result, NUCs commercialization increased significantly, with additional 4,450 tons of cassava and 13,995 tons of sorghum marketed, compared to the quantities in 2017. Overall, this Project directly benefited 176,254 individuals.

Recognizing the role of financial access in boosting NUCs, the Cameroonian government is also facilitating partnerships between NUCs producer organizations and financial institutions. For instance, the government has supported a loan initiative between the Cameroonian Association of Banana-Plantain Actors and La Régionale Bank (FreshProduceMEA, 2024). The loans will vary from USD 16,000 to USD 409,000, payable for up to 8 years, and the government offers a 50 percent guarantee for each loan. Since May 2024, when the agreement was signed, La Régionale Bank has aimed to provide loans to up to 500 plantain farmers annually, conditional on farmers receiving agribusiness training to develop bankable business plans. This initiative aligns with the government plan to increase annual plantain production from 6 million tons to 10 million tons and average yields from 6.8 ton/ha to 16 ton/ha by 2030 and make plantains Cameroon's top export product by 2035 (Dépigny et al., 2019; FreshProduceMEA, 2024; Xinhua, 2024). These targets also align with Cameroon's development strategy (SND30), which has included plantains in the list of priority crops (IITA, 2024).

Researchers at the University of Dschang in Western Cameroon are also working on conserving some NUCs at the University's botanical garden. Starting with a grant from the Ministry of Agriculture to develop a tree nursery and nutrient-rich orchards, Felix Meutchieye and his team initially operated on a 1.5-hectare plot, which was later expanded to a 14-hectare botanical garden. In this garden, several NUCs are grown, such as bitter kola, Ensete banana, moringa, chayote (*Sechium edulis*), African pear

(*Dacryodes edulis*), African yam (*Dioscorea bulbifera*), and various traditional and neglected tree species like *Pinus carribea*, *Gmelina arborea*, *Draceana arborea*, *Raffia fanifera*, and *Ricinodendron heudelotii*. In particular, the garden has reintroduced the native red kola from Hohenheim, Germany, which was exported during the German colonial era in Cameroon. Moreover, the botanical garden's management and technical teams are collaborating with organizations like ICRAF, INBAR (International Bamboo and Rattan Organization), and the civil society for agroforestry extension. Thanks to these collaborations, five village nurseries have been created, bamboo growers in the region receive extension services, and the team provides tree species for carbon sequestration and landscaping. This initiative conserves many neglected crop and tree species, contributing to biodiversity enhancement and landscape restoration. In the long run, the botanical garden has the vision to expand its portfolio to establish a living plant lab, maintain wetland spots, and create an open space for community recreation and environmental education.

Cameroonian public institutions also collaborate with the private sector and civil society to promote the consumption of NUCs-based diets. For instance, since 2022, the Ministry of Tourism and Leisure has collaborated with the Network of Restaurateurs for the Promotion of Cameroon's Culinary Heritage (CRESPAC) to organize the annual Festival of Flavors of Cameroon and the World. The Festival's third edition took place in Yaoundé during the last week of November 2024 and spotlighted Ndolé, a beloved Cameroonian dish made with bitter leaves, peanuts, and spices. This dish is in the process of being certified by the World Intellectual Property Organization (WIPO), which is expected to promote its heritage, and potentially increase the utilization of bitter leaves and peanuts (Business in Cameroon, 2024).

Furthermore, one collaborative initiative by local and Afro-American chefs organizes a so-called diaspora kitchen festival to promote NUCs-based Cameroonian cuisines. Their 2024 edition featured Koki and Folére dishes, which are based on cowpea and hibiscus, respectively. The event organizers aim to codify and popularize traditional Cameroonian cuisine, especially in the hospitality industry (Africanews, 2024). This is achieved through the training of local hotel and restaurant chefs on how to prepare and promote several NUCs-based traditional Cameroonian dishes.

Overall, the prevailing policy frameworks and government and partner programs in Cameroon prioritize a narrow group of staple crops, with little to no attention to NUCs. The ongoing multi-stakeholder policy dialogue supported by the Technologies for African Agricultural Transformation Program is considering some neglected crops, such as high-iron bean, cassava, orange-fleshed sweet potato, plantain, sorghum, and millets – a crucial step in the right direction. This will pave the way for a new seed policy that is inclusive of NUCs and creates the enabling environment for greater access, affordability, and utilization of improved NUCs' seeds, which will significantly contribute to addressing widespread malnutrition and environmental challenges across Cameroon. However, government initiatives are not enough to increase the uptake of NUCs. Increasing demand for such crops is equally important and requires long-term behavioral change strategies. To that end, sociocultural events, such as those promoting NUCs-based diets have a pivotal role to play. Therefore, demand-driven cross-collaboration among the government, NGOs, research institutes, and the private sector, and in particular, involving farmers in the decision-making process will be essential for increasing the uptake of NUCs in a drive to transform Cameroon's food systems.

4.2. Tanzania

In the past two decades, Tanzania has experienced remarkable economic growth that has recently transformed the country into a lower-middle-income country. However, the growth rate of Tanzania's agricultural sector has remained low at around 4 percent for the past several years (IFAD, 2024; USAID, 2023). This is primarily attributed to the dominance of inefficient subsistence farming, relying on manual labor and rainfed agriculture, which accounts for approximately 80 percent of the country's agricultural production (IFAD, 2024).

Tanzania has abundant natural capital, which remains underutilized in enhancing agricultural productivity and resilience. The country has 6.1 percent of its surface area covered by freshwater, a 1,424 km coastline along the Indian Ocean, and 44 million hectares of arable land, including 29.4 million hectares suitable for irrigation (TIC, 2024). Despite all these resources, Tanzania still imports significant amounts of cereals and legumes. Tanzania's agricultural sector is highly susceptible to weather shocks, with the government facing an annual financing gap of $3.4 billion to effectively address climate change challenges (AfCoDD, 2024; IFAD, 2024).

Persistent food production constraints have contributed to widespread food and nutrition insecurity affecting millions of Tanzanians. Despite a reduction in the prevalence of undernutrition from 32 percent in 2000 to 23.8 percent in 2023, 15.5 million Tanzanians remain undernourished, which has led the Global Hunger Index Report to classify Tanzania as a country facing a serious level of hunger (Wiemers et al., 2024).

Despite a notable decline in child malnutrition over the past two decades, child stunting in Tanzania remains high at around 30 percent in 2024, categorized as "very high" by the Global Hunger Index. Child wasting was around 3.1 percent in 2024 compared to 5.6 percent two decades earlier (Figure 6). Moreover, roughly two in five women of reproductive age still suffer from iron-deficiency. At the same time, the increasing prevalence of overweight and obesity across most age groups in Tanzania highlights the dual burden of undernourishment alongside the growing consumption of low-quality foods. The prevalence of obesity in the adult population (aged 18 or above) has risen from 3.7 percent in 2000 to 12.6 percent in 2022, highlighting a significant shift in dietary habits (Figure 6).

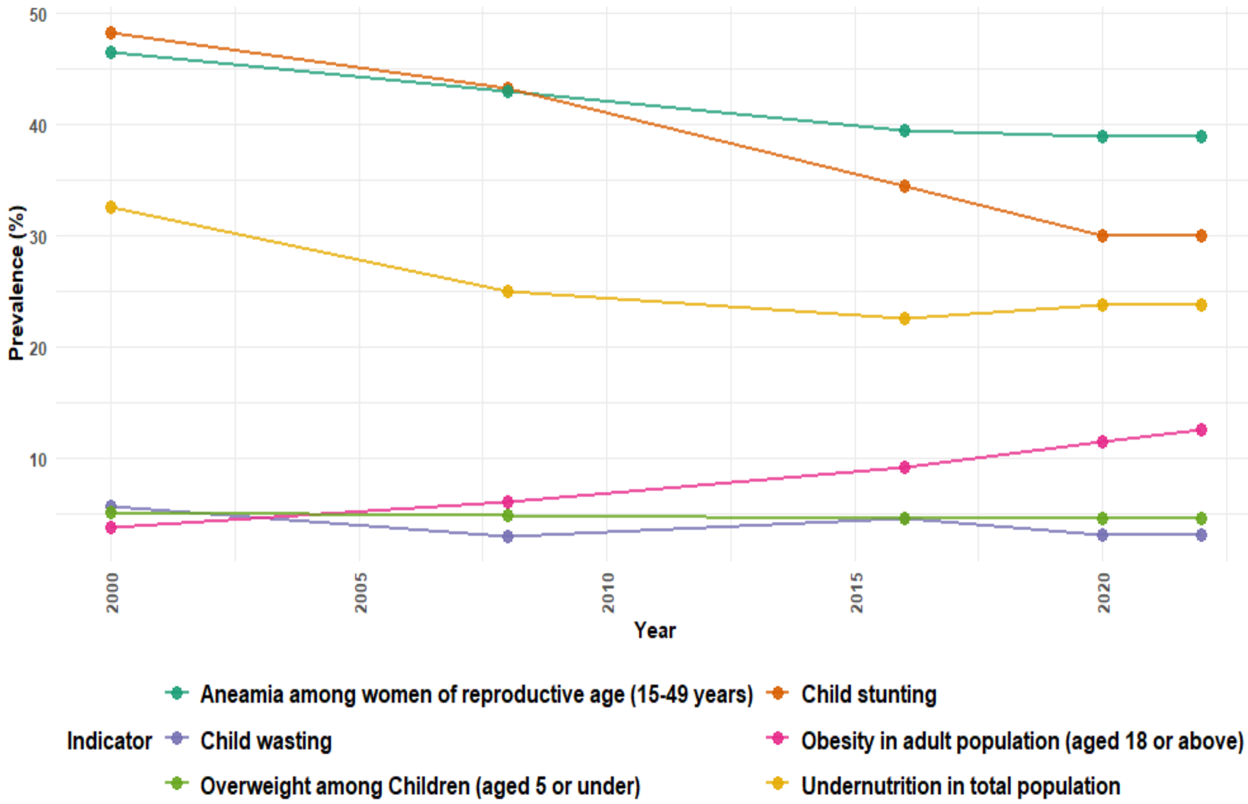

Figure 6: Evolution in nutrition indicators in Tanzania

Source: FAO (2024a) and Wiemers et al. (2024)

Several NUCs in Tanzania, including cereals, legumes, vegetables, and roots and tubers have the potential to tackle the country's malnutrition and climatic vulnerability challenges. Yet, their production and consumption remain small (Figure 7), largely because most are only produced to fulfil household consumption needs.

Status of NUCs production and consumption

Cassava production in Tanzania has shown stagnant yields over the past two decades, with the 2023 national average at 6.45 tons/ha, slightly below the 2000 level of 6.6 tons/ha. This contrasts with higher yields of around 10 tons/ha recorded between 1977 and 1997, indicating potential for significant improvement. To re-vitalize and increase cassava yield, the Tanzanian government launched the National Cassava Development Strategy (NCDS) (2020–2030), aiming to boost R&D, improve cassava varieties, and enhance the value chain. The strategy targets a yield of 16 tons/ha and an annual production of 24 million tons by 2030 (Kilimokwanza, 2023).

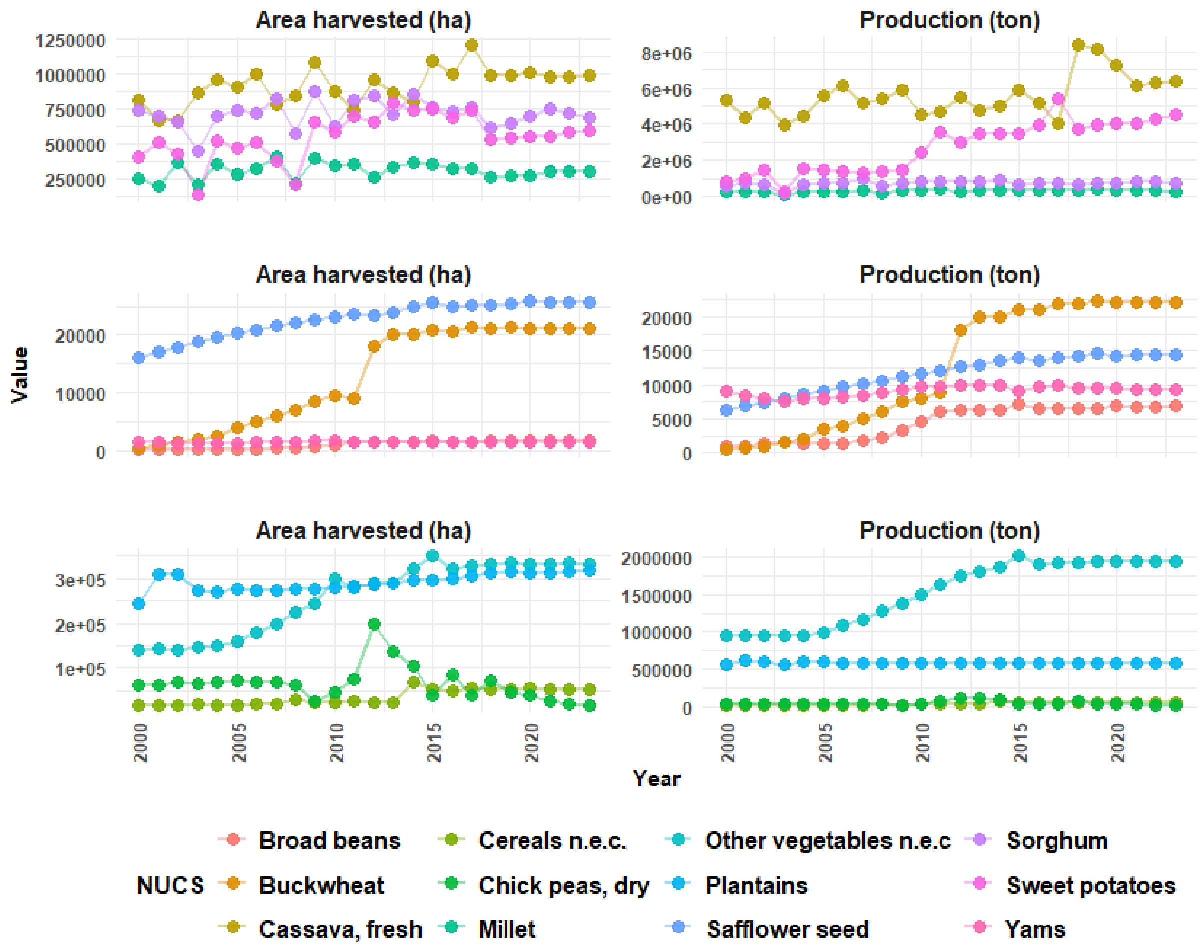

Figure 7: Evolution in selected NUCs production in Tanzania

Source: FAOSTAT (2024)

The production of chickpeas and broad beans remains undervalued despite their potential to address protein and iron deficiency in Tanzania. These legumes belong to the Fabaceae crop family, comprising other NUCs, such as Lablab bean (locally known as Ngwara), which is also nutrient rich and improves soil fertility but remains underutilized in Tanzania. Farooq & Siddique (2023) highlight that lablab beans in Tanzania face challenges such as flower drop caused by limited pollination and heat stress, risking the legume's decline in use. Farmers in Northern Tanzania have engaged in a participatory breeding program for lablab beans, aiding in its germplasm conservation and the selection of preferred traits. However, the crop’s supply is still hindered by challenges such as disease and pest infestations, including aphids in the fields and bruchids during storage (Letting et al., 2022). The authors report that over three-fourths of lablab producers are in older age groups, and approximately 87 percent of these farmers cultivate lablab on plots smaller than 0.9 hectares. Lablab is locally used for its green beans, leaves, dry beans, and occasionally as animal feed and organic fertilizer. Despite this versatility, the crop's yields remain between 0.4 and 0.6 ton/ha (Letting et al., 2022), highlighting a need for agronomic improvements to tap into its nutritional and ecological benefits.

Another neglected leguminous crop in Tanzania is Bambara groundnut, which is locally known in Swahili as "Njugu mawe" (Farooq & Siddique, 2023). One of its local varieties with the so-called DodR genotype is known to have deep taproots and efficient stomatal gas exchange, increasing its adaptation to dry growing conditions (Mateva et al., 2022; Farooq & Siddique, 2023). The crop is primarily grown to meet household food demand and its market demand is mostly non-existent, discouraging farmers from cultivating it as a main crop (Boulay et al. 2021). Interviews with experts at the Tanzania Alliance for Biodiversity (TABIO), who are partnering with SWISSAID to revive Bambara groundnut cultivation, revealed that its reputation as "food for the poor" and the lengthy preparation time discourage its utilization among both farmers and consumers. Additionally, the lack of reporting on the crop's production by the National Bureau of Statistics (NBS) and FAOSTAT highlights its underutilization.

Buckwheat is another neglected crop with remarkably untapped potential in Tanzania. The latest FAOSTAT data indicate that almost all buckwheat production in Africa takes place in Tanzania and South Africa. Production has been sharply rising over the years as shown in Figure 7. In 2023, Tanzania produced 22,190 tons of buckwheat on an area of 21,218 hectares, while South Africa produced 222.59 tons on 553 hectares. For Tanzania, this marks an increase from 400 tons harvested on an area of 500 hectares in 2000, reflecting a nearly forty-fold expansion in harvested, yet with only a marginal rise in buckwheat yield. This trend indicates that local demand for buckwheat has significantly outpaced its productivity, raising concerns about sustainability.

The area harvested and production of sorghum has fluctuated over the past two decades with marginal improvements in annual yields. Sorghum output increased from 598,200 tons in 2000 to peak at 971,198 tons in 2007, before declining to 737,819 tons in 2023. Similarly, the harvested area rose from 736,200 hectares in 2000 to peak at 874,219 hectares in 2009, then decreased to 683,967 hectares in 2023. These trends might indicate that many Tanzanian farmers have recently preferred other crops, but the marginal increase in yield from 0.8 ton/ha in 2000 to 1.08 ton/ha in 2023 at the national level highlights that there have been investments in improving sorghum productivity.

Similar to sorghum, millet production in Tanzania has experienced fluctuating annual harvest area and output with notable improvements in annual yield. In 2000, millet production was about 219,000 tons and then peaked at around 397,069 tons in 2011, later declining to 282,000 ton in 2023. The harvested area followed a similar trend, starting at 219,000 hectares in 2000, peaking at 400,000 hectares in

2007, and then declining to 300,000 hectares in 2023. Millet's yield increase also paralleled that of sorghum, rising from 0.87 ton/ha in 2000 to 1.1 ton/ha in 2022. Despite this slow development, the WFP monthly food price surveys[7] indicate that Pearl millet and finger millet are consistently present at markets across Tanzania, highlighting their importance in local consumption.

The productivity challenges are also reported in plantain/cooking banana and yam. Despite a massive increase in harvested area from 242,800 ha in 2000 to 317,834 ha in 2023, production quantity has remained relatively constant, leading to a yield decline from 2.3 ton/ha in 2000 to 1.8 ton/ha in 2023. Similar to cassava, the annual plantain yield was around 2.5 ton/ha between 1961 and 2000, indicating that addressing the current growing condition challenges can help farmers increase their plantain productivity, stimulating higher utilization. In the case of yam, the evolution in harvested area and production quantity have experienced negligible fluctuations during the past two decades (Figure 7), alluding to poor market conditions. The local yam and taro varieties take six to twelve months to mature and require high costs of production, mainly through extensive labor requirements (The Citizen, 2017). Starting from 2015; scientists at the University of Dar es Salaam started a project using micropropagation and tissue culture technologies to increase the production of quality yam and taro seedlings, addressing farmers' limited access to improved variety and planting materials.

Safflower is another globally neglected oilseed crop, which is well adapted to Tanzania's agroecology. Tanzania is ranked the ninth producer of safflower among 60 countries that grow this crop commercially (Farooq & Siddique, 2023). Its harvested area in Tanzania has increased by around 60 percent from 16,081 ha in 2000 to 25,719 ha in 2023. The output increased by around 130 percent from 6,239.98 tons in 2000 to 14,334.04 tons in 2023. Despite this seemingly significant improvement, the yield of 0.6 ton/ha in 2023 is still poor. Greater attention focused on increasing its productivity can improve this crop's supply of vegetable oil, which is rich in monounsaturated fatty acids, and tap its potential for improving soil health.

Enabling environment: Existing policies, regulations, and strategies

The existing agri-food policy environment in Tanzania prioritizes the productivity of major crops at the expense of NUCs. Currently, only four food crops (maize, rice, bean, and sunflower) undergo seed certification, and combined, they account for 71 percent of the area harvested for field crops (AGRA et al., 2024). Moreover, the latest National Five-Year Development Plan 2021/22–2025/26 (FYDP III) adopted a focused investment in the productivity of crops that directly contribute to GDP growth and

[7] The latest data can be found via https://data.humdata.org/search?q=tanzania+prices

export revenues. The priority crops in FYDP III include maize, rice, cotton, cashew nut, tea, coffee, tobacco, sisal, palm, wheat, soybean, cocoa, cassava, sugarcane, horticulture, and sunflower (MOF, 2021). The Tanzanian government seeks to increase the role of commercial crops, which currently contribute approximately 27 percent to GDP and 24 percent to total exports (MOF, 2021). This focus continues to encourage farmers to drop the low-yielding NUCs in favor of a few marketable crops, endangering agricultural and food diversity.

The national seed policy instruments have yet to acknowledge the role of NUCs in their frameworks. Prevailing instruments include:

- National Agriculture Policy of 2013, which covers the seed sector
- Seed Act 2003, with amendments made in 2014
- Seed Regulations of 2017, with amendments made in 2020.
- Plant Health Act of 2020
- Seeds (Control of Quality Declared Seed) Regulations of 2020

The key institutions in charge of regulation and development of Tanzania's seed sector include:

- The Tanzania Official Seed Certification Institute (TOSCI): a branch of the Ministry of Agriculture mandated with regulating the seed sector
- The Tanzania Agricultural Research Institute (TARI): responsible for overseeing public breeding initiatives.
- The National Plant Genetic Resource Center (NPGRC): responsible for the collection, characterization, and maintenance of plant genetic resources
- The National Variety Release Committee (NVRC): responsible for evaluating applications for the release of improved crop varieties
- The Tanzania Seed Trade Association (TASTA) working to bring together seed producers and distributors.

Despite the dominance of informal seed systems in Tanzania, the current system seems to favor seed capitalism at the expense farmer-managed seed systems (FMSS). The formal seed system accounts for around 25 percent of the seed market and the supply of certified seeds is controlled by a small group of transnational corporations, a few private seed companies, and philanthropic organizations, making access to quality seeds challenging for most Tanzanian smallholders (AFSA, 2022). Most of these smallholders cannot afford quality seeds and resort to reusing the seeds they save from their previous harvests (AFSA, 2022; Marechera et al., 2016).

Addressing these seed access challenges requires farmer-centric regulations. The Quality Declared Seed (QDS) regulation of 2020 legitimized a semi-formal seed system, where smallholders and producer groups can produce seeds in conformity with the required quality standards and sell those seeds to other farmers at affordable prices, albeit only in districts where those seeds are produced (AFSA, 2022; Kapinga, 2021). QDS regulation also strengthened the position of vegetatively propagated crops in the seed policy framework, including potato, sweet potato, and cassava (Kapinga, 2021). Building on this, the government can invest in capacity building to equip smallholder communities with the knowhow to produce and preserve quality and affordable seeds.

Government and partner projects targeting NUCs

Civil society organizations and international NGOs are taking the lead in efforts to revive NUCs in Tanzania. Organizations like the Tanzania Alliance for Biodiversity (TABIO), SWISSAID, the Swiss Research Institute of Organic Agriculture (FiBL), the Alliance for Food Sovereignty in Africa (AFSA), Crop Trust, and the World Vegetable Center have made commendable contributions to conserving the genetic resources of NUCs and raising awareness about these crops' benefits for biodiversity conservation and nutrition security in Tanzania.

TABIO brings together civil societies and private sector organizations concerned with agricultural biodiversity in Tanzania. It envisions suitable agricultural systems that guarantee food sovereignty and agrobiodiversity conservation in Tanzania (TABIO, 2025). By strengthening a coalition of farmers and consumers directly affected by the rising agrobiodiversity loss, TABIO advocates for the public acceptance of farm-saved seeds, which the current laws give no recognition. This has involved organizing local seed and food fairs and seed stakeholders' fora to draw the public's attention and get more people involved in agrobiodiversity conservation. Beyond practice, TABIO also engages in policy dialogues, striving to integrate farm-saved seeds into legal frameworks. Their recent recommendations include implementing agricultural biodiversity monitoring and evaluation, promoting farmer-to-farmer seed exchange mechanisms and seed fairs, testing the suitability of indigenous varieties to different ecological zones, and establishing more community seed banks. Furthermore, TABIO implements the projects of The Seed Working Group, a collaborative initiative under the Alliance for Food Sovereignty in Africa (AFSA), focusing on seed sovereignty and the preservation of indigenous seed systems across Africa. This has involved campaigns like Seed is Life, which aimed to uphold Farmer Managed Seed Systems, and My Food is African, which focused on promoting traditional foods, dishes, and cuisines. My Food is African campaign rallied African youths, chefs, health experts, teachers, and other influential individuals to increase awareness of the health benefits of indigenous crops and shape the narrative around food in Africa (AFSA, 2023).

One of the NGO initiatives spearheading the revival of NUCs in Tanzania is The Consumption of Resilient Orphan Crops for Products for Healthier Diets (CROPS4HD) Project by a consortium of SWISSAID, FiBL, and the Alliance for Food Sovereignty in Africa (AFSA). Also implemented in Chad, Niger, and India, CROPS4HD aims to make traditional crops and varieties more attractive by demonstrating their nutritional benefits, supporting farmers to improve their cultivation techniques to achieve good yields and strengthening farmers' seed systems by protecting farmers' rights to propagate, exchange, and sell their seeds in project countries (SWISSAID, 2021). In Tanzania, the project focuses on two southern regions, Lindi and Mtwara. The work on NUCs promotion targets rural markets and schools, encourages the integration of NUCs in urban organic markets, and develops e-ordering and home delivery services. These strategies align with the Project's targets, such as increasing weekly consumption of NUCs in Tanzanian diets by 20 percent, increasing farmers' access to NUCs seeds by 30 percent, and improving the incomes, food security, and climate resilience of 8000 farmers.

CROPS4HD promotes the production and consumption of twelve crops/crop-based products, including Bambara groundnut, finger millet, amaranth leaves, amaranth grains, pumpkin, African eggplant, African nightshade, spider plant, sweet potato leaves, bungo, and sugar apple. It also supports NUCs-based value chains to enhance the commercialization of nutritious flours mixed with finger millets, Bambara nuts, sesame oil, sesame-based biscuits, and processed eggplant and pumpkin seeds. Furthermore, the Project staff has developed a cookbook highlighting around 25 NUCs-based recipes for various dishes including starters, mains, sides, and condiments, as well as desserts. Starter recipes include amaranth fritters and hummus, salads, shakusha, and falafels made using Bambara nuts. The latter is also a key ingredient for pasta recipes, such as ravioli and tagliatelle. The cookbook also displays other notable NUCs-based main course recipes, including pumpkin pots, amaranth casserole, and African eggplant stew. Moreover, displayed recipes for desserts include the use of soursop as a flavor for trifle, bungo fruit for cheesecake and sorbet, sugar apple for tiramisu and cheesecake, African nightshade for muffins, and finger millet for brownies. The Project's mission also extends to community activism. CROPS4HD staff contributed to the preparation and implementation of the 2024 edition of the annual Nanenane Exhibitions Week, which featured a NUCs Seed and Food Fair. The highlights included a NUCs seed exchange session, advocacy for farmer-managed seed systems, a cooking demonstration, and an exhibition of local dishes featuring NUCs. The latter emphasized the health benefits and the role of NUCS-enriched recipes in enhancing the nutritional well-being of communities while addressing challenges like malnutrition and stunted growth (CROPS4HD, 2024).

A consortium of three Belgian NGOs (SOS Faim, Iles de Paix, and Autre Terre) also implemented the Kilimo Endelevu (Swahili translation for sustainable agriculture) Project with a NUCs component from 2017 and 2021. The Project was extended as Kilimo Endelevu+ in 2020 and ended in 2023, positively impacting eight local seed banks and more than 5000 people in the Arusha region (IDP, 2022; IDP, 2024). Besides, Iles de Paix alone distributed 86,000 orange-fleshed sweet potato plants to more than 780 households by 2023 (IDP, 2024). In addition, the organization has collaborated with leading international partners like IITA, World Vegetable Center, and RECODA to implement the USDAID-funded AFRICA RISING Project in the Arusha region. AFRICA RISING has adopted the farmer-to-farmer training approach to facilitate an easy diffusion and scaling of improved farming technologies in target crops, including traditional vegetables. The Project also organizes field days and learning events to sensitize farmers about the nutritional benefits of traditional crops and demonstrate some recipes made of crops like pumpkin, amaranth, chayote, and pigeon pea. The World Vegetable Center is also promoting the keyhole garden technology and other vegetable farm management practices including the use of marigold flower as an insect repellent to control nematodes and castor oil seeds to produce organic pesticides. Thanks to these interventions, Project beneficiaries have reported an increased production, consumption, and commercialization of neglected crops including African eggplant, African nightshade, Ethiopian mustard, amaranth, jute mallow, sweet potato leaves, cassava leaves, and Chaya (AFRICA RISING, 2022).

Moreover, the Crop Trust is implementing the BOLDER (Building Opportunities for Lesser-known Diversity in Edible Resources) Project in Tanzania, targeting NUCs such as Bambara groundnut, breadfruit, Brassicas, finger millet, grass pea, taro, and yams (Crop Trust, 2024). This Project embraces a needs-based approach that promotes participatory conservation and breeding of NUCs that are valuable to communities. BOLDER engages farmers and consumers to evaluate the selected NUCs and their developed varieties, aiming to address the local market needs. It also works with research institutes and gene banks to increase the diversity of collected NUCs' genetic materials and streamline their documentation and conservation, including back-ups in the Svalbard Global Seed Vault. Furthermore, working with local value chain partners, the Project engages in promoting the cultivation and production of selected NUCs, aiming to increase their market availability and consumption, consequently improving food security and farmers' resilience.

The Nelson Mandela African Institution of Science and Technology (NM-AIST) in Arusha also hosts a gene bank, which is conserving several neglected legumes. The gene bank boasts a collection of 1596 legume germplasms with 52 for Bambara groundnut and 258 for lablab bean (Venkataramana, 2023). Cowpea accounts for the largest number of accessions amounting to 335, with green gram, horse gram, Lima bean, moth bean, pigeon pea, rice bean, and tepary bean also featuring on the list. NM-AIST conducts trials of different varieties of these legumes and involves local farmers to factor their preferences on planned seed multiplications. This initiative envisions a future where these leguminous NUCs are more productive, appealing to more farmers, and contributing to a great supply of protein-rich food and animal feed.

Furthermore, the World Vegetable Center is championing the revival of Indigenous African Vegetables (AIVs) that have been falling into disuse in the past decades. With funding from the Taiwanese government, the Center implemented the Taiwan-Africa Vegetable Initiative (TAVI), a three-year project from 2021 to 2023, which focused on conserving the diversity of AIVs and increasing their production and consumption for food and nutrition security in Africa (WorldVeg, 2024a). This initiative culminated in the opening of Africa's vegetable gene bank at World Vegetable's Regional Center for Eastern and Southern Africa in Arusha, Tanzania, in March 2024. Beyond the conservation of genetic resources, the World Vegetable Center also works on AIV research and development. For instance, as a result of the Center's amaranth breeding program, which started in 2004, 66 percent of the amaranth production in Tanzania relies on improved varieties with yields that are 6.1 ton/ha higher than those of other cultivars (Wanyama et al., 2023). Van Zoneveld et al. (2023) report that the World Vegetable Center and its local research partners engage local vegetable farmers in participatory breeding and evaluations of vegetable varieties, contributing to greater adoption of AIVs, such as amaranth, spider plants, and okra.

The Tanzanian case study highlights a lack of government projects targeting NUCs, which leaves many farmers of neglected crops trapped in a gridlock of low productivity, malnutrition, and vulnerable livelihoods. The changing dietary habits and the associated health risks also show that Tanzanian consumers would be better off being aware of NUCs' nutrition benefits and having a greater supply of nutritious NUCs, such as protein-rich legumes and micronutrient-rich AIVs. Despite the government's neglect of this reality, the discussed NGO and international initiatives have contributed to the promotion of farmer-managed seed systems, participatory crop selection and breading, awareness campaigns, and policy dialogues, which are crucial steps to increase the uptake of NUCs. However, many civil societies and NGOs rely on donor financing with fixed timelines, which raises concerns about the sustainability of their important contributions. Therefore, the government needs to collaborate with active players in the NUCs subsector to facilitate policy and market innovations that promote the sustainable production and consumption of NUCs as an avenue for addressing local malnutrition and ecological challenges.

5. Conclusion and policy recommendations

Despite global efforts, malnutrition persists in various forms, including undernourishment, micronutrient deficiencies, and overweight and obesity. Meanwhile, rising food demand, coupled with climate change and land degradation, is reducing crop yields, worsening food insecurity and malnutrition. Addressing these challenges requires building resilient and sustainable agrifood systems that provide nutritious diets. A critical aspect of this transformation is cultivating diverse, nutritious, and climate-resilient crops.

The development of value chains for neglected and underutilized crops (NUCs) presents a strong opportunity for food system transformation. NUCs can contribute to enhancing food security and nutrition while addressing socioeconomic and environmental challenges. These crops are rich in macronutrients such as protein (e.g., quinoa, teff, rice, bean), healthy fats (e.g., Bambara groundnut, amaranth, finger millet), and carbohydrates (e.g., fonio, finger millet, cassava). Additionally, NUCs are great sources of essential micronutrients like vitamin A, iron, calcium, and zinc, found in crops such as millet species, groundnuts, yam, and baobab. Many NUCs have the potential to address persistent micronutrient deficiencies that affect around 3 billion people globally. Their climate resilience and adaptability to marginal environments make them a sustainable contribution to biodiversity and food security.

However, despite the numerous benefits, the potential of many NUCs remains untapped. This paper highlights various challenges: on the production side, challenges include limited seed availability, insufficient NUCs-focused research and development, outdated production and processing technologies, underdeveloped infrastructure, limited market access, and scarce investments. On the demand side, issues of availability, accessibility, affordability, and desirability persist. NUCs are sometimes perceived as "food for the poor", creating cultural barriers that hinder their adoption.

To increase NUCs uptake, especially in African countries facing rising food demand and climate change impacts, governments, private sector companies, research institutions, and NGOs must collaborate. This includes addressing production challenges, advocating the benefits of NUCs, and developing innovative, culturally adaptive strategies to boost their consumption. Nutrition-centered social behavioral change (SBC) strategies have an important role to play. Increasing the production and consumption of NUCs could also help reverse the preference for calorie-dense, nutrient-poor diets, contributing to better nutrition and more sustainable food systems.

Policy recommendations

We recommend the following interventions to increase the uptake of NUCs, emphasizing the need for holistic and integrated approaches that address the interconnected nature of the challenges and constraints.

- **Research and development (R&D) and seed systems:** Investment in R&D is crucial to improving breeding, production, and processing technologies for NUCs. Priorities include enhancing seed availability and resilience to pests and diseases, modernizing production methods, and addressing post-harvest inefficiencies like manual processing and anti-nutritional factors. For precise and rapid breeding progress in NUCs, genomic techniques provide cost-effective opportunities, which should be harnessed alongside traditional breeding approaches. Strengthening seed distribution systems, establishing gene banks, and promoting multilateral collaborations are essential for sustainable seed access and improved production outcomes.

- **Infrastructure and market access:** Limited infrastructure, including inadequate breeding stations, seed multiplication, storage, and processing facilities, hampers the adoption of NUCs among farmers and the development of efficient markets. Comprehensive value chain development, improved transportation, and targeted investments in rural infrastructure are key. Addressing these barriers will enhance the economic viability of NUCs, enabling better market access and increasing their competitiveness.
- **Institutional and knowledge gaps:** Incorporating NUCs into agricultural policies and fostering public-private partnerships can address institutional shortcomings. Governments should reallocate resources to support NUCs alongside commercial crops, enhance funding for training programs, and collaborate with research institutions and NGOs to develop and promote education on NUCs in agricultural programs. More investment into outreach efforts, such as on-farm demonstrations and extension services, could boost awareness and adoption.
- **Social behavioral change (SBC) strategies:** SBC strategies are essential for promoting the consumption of NUCs by addressing cultural norms and preferences. Integrating interpersonal communication, social change, community mobilization, mass media, and advocacy can help to promote and sustain impactful nutrition practices and raise awareness about the nutritional and environmental benefits of NUCs. Such efforts should be context-specific, leveraging private sector and NGO expertise and involving local community leaders to design effective strategies.
- **Regional trade and policy integration:** Harnessing opportunities like the African Continental Free Trade Area (AfCFTA) can enhance regional trade of NUCs, fostering economic growth and resilience. Integrated policy agendas aligning biodiversity, nutrition, and climate goals should prioritize NUCs to create synergies across countries and sectors.
- **Supporting smallholder farmers:** Empowering smallholder farmers through access to funding, technology, and training is critical for scaling up NUCs production. Initiatives like community seed banks can enhance climate adaptation, conserve plant genetic resources, and improve nutrition outcomes, thus improving resilience and uptake among farmers**.**

- **Private sector and community initiatives: Encourage local innovations that enhance production efficiency of NUCs.** Sanoussi Diakité's invention of a fonio processing machine that makes processing faster than manual processing in Senegal is an interesting example. Policy should support initiatives that organize awareness campaigns and training programs, prioritizing the engagement of youths and women producer organizations to increase adoption. Interest by private sector players can be crucial. For instance, companies like Yolélé Foods have increased the visibility of fonio in international markets. The company has partnered with West African fonio farmers, invested in a fonio processing factory, and showcases the versatility and high nutrient content of fonio. Such efforts can strengthen value chains and stimulate demand for NUCs both locally and globally.
- **Multilateral and global campaigns:** Efforts such as FAO's declaration of 2023 as the "Year of Millets" and its social media campaign to highlight various recipes underline the role of global campaigns in terms of promoting NUCs. However, global campaigns can also have undesirable side-effects, as the quinoa example shows. Such effects should be understood and avoided through appropriate measures. Initiatives like the Vision for Adapted Crops and Soils (VACS) and capacity-building programs for NUCs producers demonstrate the potential of international collaborations to drive awareness, productivity, and market access for NUCs.
- **Expanding international markets:** Efforts to increase the global visibility of NUCs, such as partnerships with retail markets and food processors, are essential. Products like fonio and teff are gaining traction in health-conscious markets, presenting significant opportunities for farmers in regions like West Africa and Ethiopia.
- **Lessons from other crops:** Insights from the quinoa boom in Latin America and teff in Ethiopia underscore the importance of ensuring that scaling efforts for NUCs are sustainable and benefit smallholder farmers and rural communities. Learning from these experiences can guide strategies for NUCs development.

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Authors: Katrin Glatzel, Cecilia C. Maina, Aimable Nyishimirente, Janosch Klemm, Matin Qaim

Contact: kglatzel@akademiya2063.org, s7cemain@uni-bonn.de, aimable1998@gmail.com, jklemm@uni-bonn.de, mqaim@uni-bonn.de

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Zentrum für Entwicklungsforschung (ZEF)
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Phone: +49-228-73-1861
Fax: +49-228-73-1869
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