Supply-side measures improving food environments

Promoting neglected and underutilized species to boost nutrition in LMICs

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INTRODUCTION

Historically, agricultural projects have been largely unsuccessful in improving the rural food environment by increasing access to and utilization of foods (Burchi et al., 2011). Agricultural projects targeting food availability and consumption have primarily focused on increasing the yields of a select few energy-rich commodity crops and raising income from the sale of these crops to improve food and nutrition outcomes. This has resulted in several crops being over-researched and over-produced (for example, rice, wheat and maize) at the cost of more nutritious food species, including fruit, vegetables and legumes, which are generally under-researched and insufficiently available.

Despite the 5 538 food crops estimated to exist globally, 75 percent of the world's food is generated from just 12 plants and 5 animal species, with only 3 plant species providing more than 50 percent of the world's food-energy needs (FAO, 2012; FAOSTAT, 2013; Royal Botanic Gardens, Kew, 2016; Yaro et al., 2017).

The continued decline in crop diversity in agricultural production systems is making global food systems significantly vulnerable. They are more susceptible to shocks, especially smallholder systems, which keep locally adapted, hardy, climate-resilient varieties and breeds alive (FAO, 2012; Kray et al., 2019), undermining their role in feeding the world sustainably (Fanzo and Mattei, 2012). Farming communities are left with fewer livelihood options for addressing the evolving needs of households and markets (Lamers et al., 2016), including the provision of diverse nutritious foods to rural food environments.

To better understand the importance of crop diversity, it is worthwhile considering the role played by food environments and how they influence our diets and health. "Food environment" is a broad concept (Box 1) and refers to the area of the food system between the acquisition and consumption of food. Food environments can vary according to context, between different urban and rural settings, or high-, middle- and low-income countries, for example.

Rural food environments in lower- and middle-income countries (LMICs) are facing a specific set of challenges. Modern retail outlets and large value chains are often not the primary source of the foods consumed every day. Many rural consumers are also food producers who rely heavily on their own production as their primary source of food, closely followed by foods produced and sourced from within their immediate local food system. Consequently, their food environment is intrinsically and directly tied to the production system within the local landscape, the health of which is also closely correlated with the richness of the diverse foods present in both the cultivated and wild ecosystems.

The narrowing diversity of production systems means rural consumers have less choice and are consuming a smaller array of foods, resulting in less nutritious and healthy diets (Wilting et al., 2017, Lachat et al., 2018). Moreover, the degradation of the natural environment and the use of pesticides are reducing the availability of and access to wild and semi-domesticated nutrient-dense foods, such as fruit, nuts and wild vegetables. Market and income development are opening up new opportunities in the food environment, but the diversity and nutritional quality of products offered in rural markets are often limited.

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Box 1. DEFINITIONS OF THE FOOD ENVIRONMENT

Food environment definitions	Perspective	Reference
"We define the food environment as the availability, affordability, convenience, and desirability of various foods."	Markets	Herforth and Ahmed (2015)
"The food environment is the interface that mediates one's food acquisition and consumption within the wider food system. It encompasses multiple dimensions such as the availability, accessibility, affordability, desirability, convenience, marketing, and properties of food sources and products."	Food system	Turner et al. (2017)
"Food environment refers to the physical, economic, political and sociocultural context in which consumers engage with the food system to make their decisions about acquiring, preparing and consuming food."	Food system	HLPE (2017)
"Food environments may be thought of as all the foods which are available and accessible to people in the settings in which they go about their daily lives. That is, the range of foods in supermarkets, small retail outlets, wet markets, street food stalls, coffee shops, tea houses, school canteens, restaurants and all the other venues where people procure and eat food."	Markets	FAO (2016)

Source: *Adapted from Bioversity International, unpublished.*

UNLOCKING THE POTENTIAL OF NEGLECTED AND UNDERUTILIZED SPECIES

In addition to making urban food environments nutritionally richer by making diverse crops and animals, varieties and breeds more available and accessible, decision makers are becoming more aware of the need to strengthen agricultural production systems through "climate smart" and "nutrition-sensitive" interventions (Li and Siddique, 2018; De la Peña and Garrett, 2018). Such initiatives are increasingly becoming key strategies for improving the food security and nutrition of rural populations, but with benefits for urban dwellers, too.

In this context, there is a growing need for better research and development (R&D) coverage of 'orphan' crops, or neglected and underutilized species (NUS) – wild and cultivated plant genetic resources that are undervalued by current food environments, even though they are often highly nutritious and resilient to climate change and could provide new income-generation opportunities (Box 2) (Padulosi et al., 2011, 2013). Bringing back NUS to food environments could improve access to and utilization of nutritious foods, leading to healthier diets (Kennedy et al., 2017).

Box 2.

WHAT IS A NEGLECTED AND UNDERUTILIZED SPECIES (NUS)?

- NUS include wild, semi- or fully domesticated plants of diverse forms (field crops, trees, shrubs, vines and others), as well as edible fungi and animal species.
- "Underutilized" refers to these species' untapped livelihood and nutrition potential.
- "Neglected" refers to the lack of investment in research of these species compared with mainstream commodities.

Many NUS have similar or better nutritional profiles than more commonly available foods (Table 1). Despite being fundamental to communities around the world (see, for example, Termote et al., 2015; Boedecker et al., 2014; Ebert, 2014;), NUS from nutrient-dense food groups, including minor cereals, pulses, fruits and vegetables, have been the subject of little research to enhance yields and overcome the challenges of cultivation, processing, marketing or consumption (Kahane et al., 2013). They are rarely covered by extension work and have been relegated to the margins of mainstream agriculture. We explore the strategic role that rural advisory services can play in promoting the sustainable use of NUS later in this paper.

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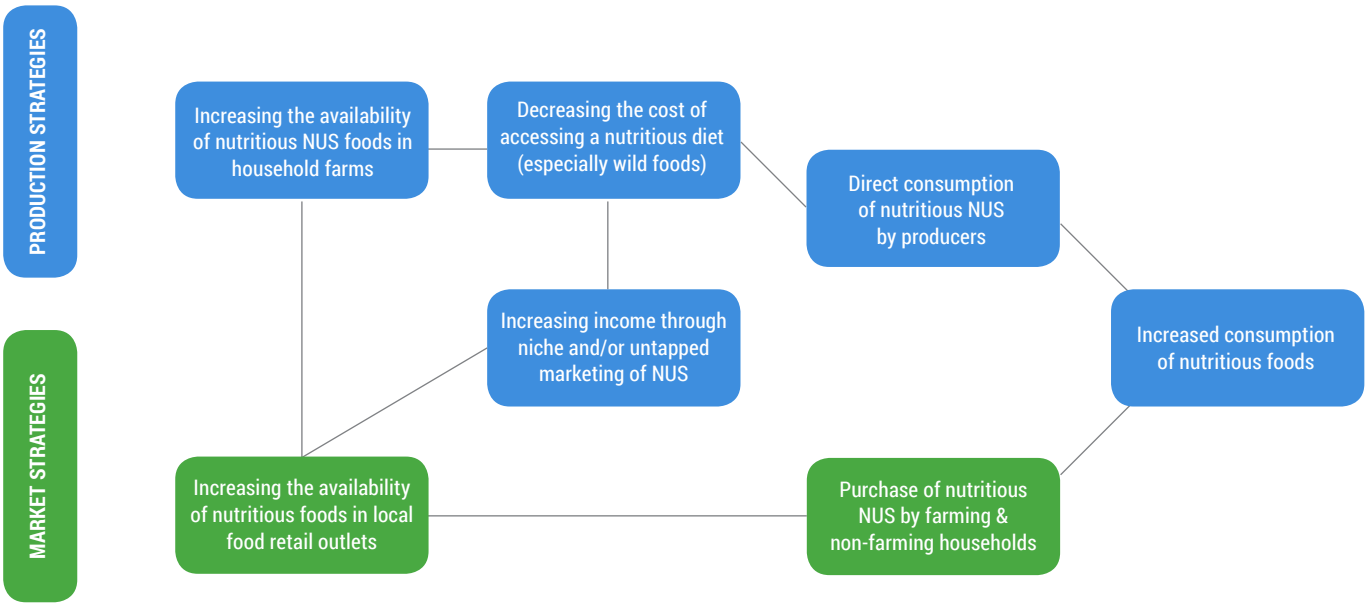
Table 1. FOOD COMPOSITION: NUTRITIONAL DIFFERENCES BETWEEN COMMONLY CONSUMED CROPS AND NUS (PER 100G)

Fruit	Ca (mg)	Fe (mg)	Mg (mg)	Zn (mg)	Vit A (mcg)	B - carotene (mcg)	Thiamine (mg)	Riboflavin (mg)	Niacin (mg)	Vitamin B6 (mg)	Folate (mcg)	Vit C (mg)
Common crops												
Apple*	6	0.1	5	0.04	3	33	0.02	0.03	0.1	0.04	3	4.6
Orange*	31	0.2	11	0.1	8	90	0.04	0.03	0.2	0.07	33	46.8
NUS alternatives												
Sugar apple	28.20	1.36	38.47	0.22			0.13	0.09	0.69	0.07	7.60	21.51
Peach palm	44.6	4.4	11.7	2.1	-							62.2
Acai berry	35	0.4					0.1	0.04				
Salak	127.3	19.1	7.16	35.1		48	0.18	0.2	2.4	1	3	20.41-35.02
African locust bean	118	3.6	88	1.4	405	2430	1.08	0.71	1.3	0		234
Wild mango	164	1.9		0.3			0.18	0.09	0.7			
Langsat	20				13		0.08	0.12				1
Jackfruit	45.74	0.31	26.6	0.37	150-540		0.05	0.05	0.19	0.04	35.73	17.51
Kumquat	266	1.7			2530							
Desert date	74-76	39			-							
Cereals, pseudo-cereals, roots and tubers												
Common crops												
Rice*	28	0.8	25	1.09	0	0	0.07	0.05	1.6	0.16	8	0
Wheat*	29	3.19	126	2.65	9	5	0.3	0.12	5.46	0.3	38	0
NUS alternatives												
Quinoa	128	94.85	190			11.87 - 17.71	0.15	0.43	1.2	0.2	78.1	1.4
Amaranth	159	7.6	270	2.52			0.16	0.36	1.1	0.33	24.65	
Elephant foot yam	50	0.6	30.4	0.33		158	0.04	0.05	0.61	0.22	20.5	15.22
Yam	35	1.2	21	0.24	138	83	0.11	0.03	0.55	0.29	23	17.1
Fonio	51	10	434	3.8	0	0	0.26	0.1	1.7	0.74	29	0
Tef	17-178	9.5-150										
Job's tears	54	0.8					0.48	0.1	2.7			
Finger millet	370	6	137	2.3	0.48	1.53	0.33	0.11	1.2	0.05	34.66	
Foxtail millet	37	6.2	81	2.4			0.48	0.14	2.4		39.49	
Little millet	17	1.26	133	3.7			0.26	0.05	1.29			
Barnyard millet	96	5	82	3	0.36		0.11	4.5	4.2			
Buckwheat	50	3.4					0.41	0.2	2.3			

* More common crops

Source: *Arora (2014); Ballogou et al. (2013); Baye et al. (2014); Brink and Belay (2006); Chweya and Mnzava (1997); Deme et al. (2017); FAO et al. (2010); Fasakin (2004); Feyssa Debela et al. (2015); Getinet et al. (1996); Gordillo-Bastidas et al. (2016); Jiri and Mafongoya (2016); Kamatar et al. (2013); Khatoon et al. (2015); Lester and Bekele (1981); Longvah et al. (2017); Government of Nepal (2012); Aremu et al. (2006); Porch et al. (2017); Puri and Surolia (1994); Puspitasari et al. (2017); Shaheen et al. (2013); Ministry of Health, Brazil (2002); Tirajoh et al. (2012); Wickens (1995).*

Figure 1. PRODUCTION AND MARKETING STRATEGIES TO PROMOTE NUS FOR MORE NUTRITION-SENSITIVE FOOD ENVIRONMENTS



Source: *Authors.*

NUS have the potential to improve access to nutritious foods in rural areas by (1) increasing the availability of nutritious foods for direct consumption by producers; (2) decreasing the cost of accessing a nutritious diet (especially wild foods); (3) increasing the availability of nutritious foods in local food retail outlets and markets for sale by producers, and/or by (4) increasing income through niche and/or untapped marketing opportunities, which could then be used to purchase other, more nutritious foods (Figure 1).

NUS with diverse phenology can be leveraged to improve food availability all year round. The edible leaves of certain woody species, for instance, can be harvested as vegetables throughout the year (for example, chaya, *Cnidoscolus aconitifolius* and *Moringa oleifera*). The tolerance of many NUS to abiotic stresses (such as drought, frost and heat) and biotic stresses (such as pests and diseases), as well as their lower water and nutrient requirements, can enable more resilient production under stressful conditions (Padulosi et al., 2011).

When income is a barrier to access to nutritious foods, wild NUS offer a low-cost alternative. These wild foods should to be harvested with potential over-harvesting and conservation issues in mind, however (Padulosi et al., 2008). Cultivated NUS also tend to require fewer agrochemical inputs than improved commercial varieties; seeds are typically sourced from local seed systems, unlike commercial hybrids and improved species. These are factors that can reduce the financial burden on farms in terms of accessing nutritious foods year after year.

Market development of NUS can increase the availability of nutritious foods in local retail outlets for rural populations. NUS can also enhance incomes by providing new and niche marketing opportunities and complementary or alternative income sources when staple crops fail. Farmers can be encouraged to allocate the additional income from these activities to the purchase of nutritious foods in local markets.

In many cases, NUS are already available, accepted and desirable. They are often found in traditional recipes, using traditional preparation methods, and it can be easier to broaden their usage than to introduce a completely new food. NUS are often managed by poor and vulnerable groups, such as indigenous peoples and women, who could benefit significantly from enhanced production, marketing and consumption (see Annex 1). Thus, NUS can be a tool to support the continuation and empowerment of indigenous local food systems and cultural identity and promote gender equality. The close link between these foods, local people, land and cultures offers a unique opportunity to revitalize local food culture and food systems and empower smallholder farmers, who are often the custodians of this agro-biodiverse resource.

WHY HAVE NUS BEEN NEGLECTED AND UNDERUTILIZED?

The shrinking diversity of our food basket and the marginalization of local crops has multiple causes, many of which can be traced back to the Green Revolution, which saw food companies impose widespread standardization of production systems to achieve economies of scale through intensified mechanization, from planting to harvesting, processing and commercialization. Moreover, the growing disconnect between consumers and traditional food cultures and the perception that traditional crops are old-fashioned and unattractive compared with modern ones have also contributed to this phenomenon.

The abandonment of hundreds of species that are, paradoxically, most useful today in fighting nutrition insecurity and tackling biotic and abiotic stresses (Altieri, 2002; FAO, 2011) is of great concern (Kray et al., 2019). Reducing the diversity of our food systems has created a situation that is no longer tenable for consumers and value-chain actors. Cultivation systems are experiencing a decline in fertility and regenerating capacity and becoming more vulnerable to climate change and susceptible to pests and diseases. Value-chain operators are finding they have fewer food choices to offer consumers for a healthy diet, who, in turn, are seeing their healthy food options dwindle (Kahane et al., 2013).

NUS hold the key to realizing a new Green Revolution driven by genetic and cultural diversity. Such a revolution is necessary to tackle the daunting problems of poverty and malnutrition in its diverse forms. Bringing these foods back to the table is also a matter of urgency, as most of these species are not available in ex situ gene banks and are likely to rapidly disappear before they are properly collected, identified and put to use (Mal, 2007; FAO, 2010).

There are hundreds of NUS from commonly consumed plant genera with untapped potential to increase the availability of nutritious foods to the world (Figure 2). Although NUS have many characteristics that could positively impact the lives of rural communities, there are specific bottlenecks causing their lack of competitiveness with mainstream crops. These constraints could be overcome with modest, but well-focused and concerted interventions by research, development and rural advisory services, however. Some of the main barriers to their wider utilization are related to production, marketing and consumption issues. These include:

1. Production- and harvesting-related barriers

The focus of research and agriculture projects has been on commodity crops, either cash crops or largely starchy staple food crops. This has left numerous agronomic bottlenecks encountered by NUS overlooked, including:

- poor availability of genetic diversity in ex situ and in situ/on-farm collections;
- poor availability of seed and other reproductive material, hindering wider use (particularly wild or semi-domesticated species);
- poor farmers' seed networks being required to support crop-diversity sharing;
- low-yielding varieties compared with hybrid, improved alternatives in the short term (but which may be more consistent over time – hybrid varieties can reduce yield over time and require heavy inputs);
- high and intense labour input associated with cultivation and harvesting; and
- the transformation of land usage, such as forest to agriculture and agriculture to housing, to accommodate increasing populations has led to changes in natural habitat and biodiversity loss, reducing the availability of wild NUS and the suitability of cultivated NUS.

2. Marketing- and value chain-related barriers

Value-chain development and marketing for NUS involve greater risk and investment, as they often involve product development, market development or diversification strategies. Investment decision-making on processing, packaging or pricing for NUS is challenging compared with commodity crops, for which information and precedent exist and are readily available. Some of the barriers include:

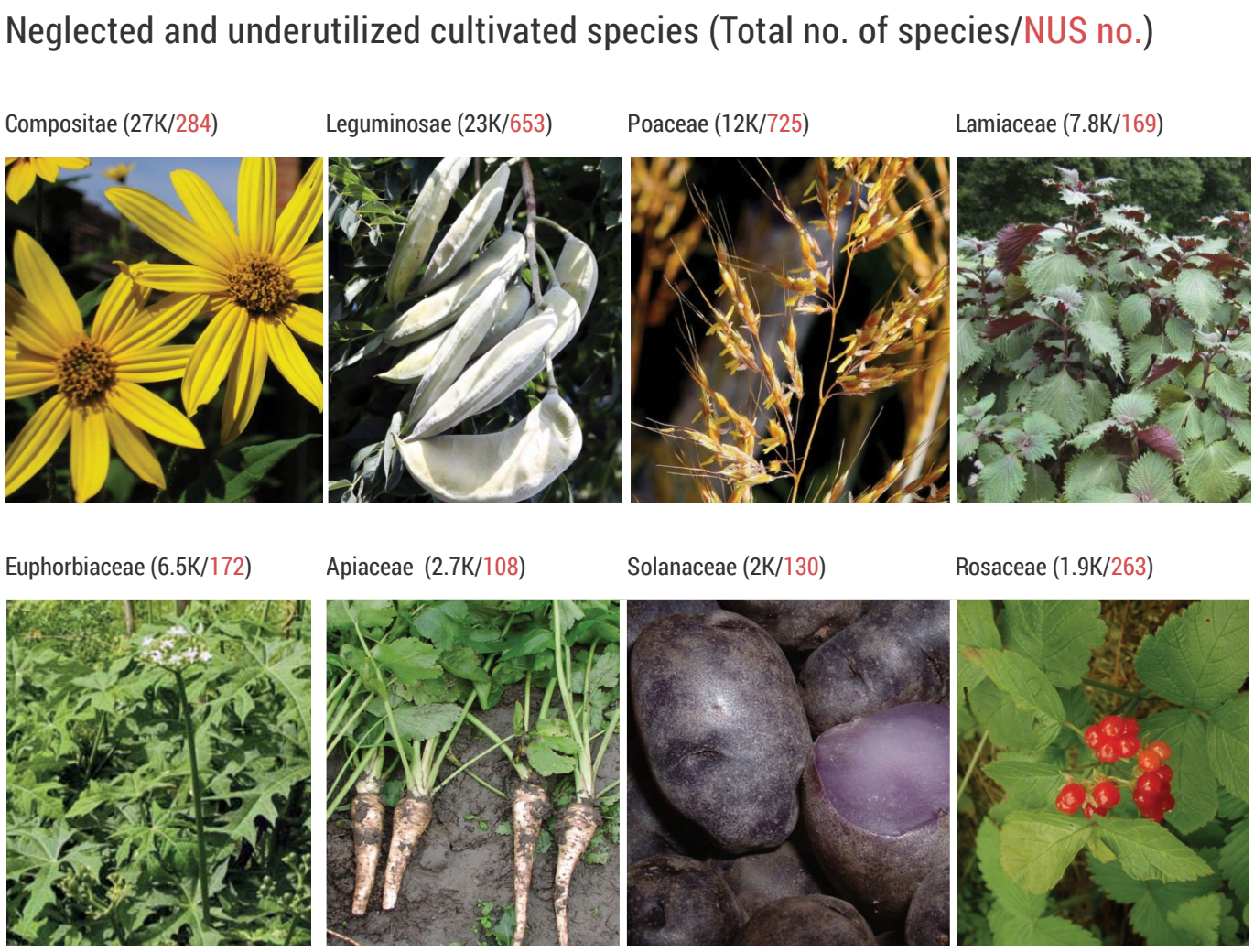
- inefficient value chains that lead to low price incentives;
- a lack of collective action and aggregation of supply;
- a lack of market knowledge and beneficial market linkages;
- a lack of entrepreneurial skills and business support services;
- a lack of proper packaging or cold chain and processing, as NUS can deteriorate quicker than hybrid varieties bred to be resistant to travel, etc.;
- high and intense labour input associated with processing, with the burden often falling on women;
- a lack of sufficient market demand from local or wider markets to justify larger-scale production; and
- policies hindering NUS marketing and value-chain development (such as subsidies or procurement that target only staple crops).

3. Consumption- and demand-related barriers

The negative perception of NUS, particularly by young people, hinders their use. They are considered "poor man's crops", foods associated with famine or periods of hardship. However, a number of large Global South economies, such as India, Brazil and Nigeria, have a substantial and fast-growing middle class and wealthy consumers in larger cities. These people are potential NUS consumers and could be targeted through their interest in connecting with their food cultures and their preference for nutritious, pesticide-free and healthy foods. However, well-conceived interventions that target the needs of lower-income households could also create strong domestic demand for these crops. Additional barriers include:

- widespread cultural erosion, leading to a loss of knowledge about food-preparation methods and the growing detachment of younger generations from ancestral foods;
- a lack of innovative food recipes that involve less cooking time and are more in tune with modern food-consumption habits and lifestyles;
- little knowledge of beneficial economic practices or the potential to improve food and nutrition security;
- a lack of consumer demand, which translates into a lack of product awareness, reducing incentives for farmers and other value-chain actors to invest in NUS development as there is limited commercial value or profit potential;
- a lack of nutritional data, undermining the case for NUS and the justification for research investment into the production of improved varieties, ultimately limiting their cultivation and consumption levels.

Figure 2. UNTAPPED NUS RESOURCES IN COMMONLY CONSUMED PLANT FAMILIES



Source: *Khoshbakht and Hammer (2008); The Plant List (2013).*

INTEGRATING NUS INTO RURAL FOOD ENVIRONMENTS: A NUTRITIONAL NEEDS-BASED APPROACH

Rural advisory services can play a key role in promoting NUS for better nutrition and livelihoods and it is important that these actors are aware of locally available NUS. It is particularly important that they promote species that can help to bridge nutrient gaps in local diets. Evaluating the constraints on the use of NUS can inform strategies to foster more effective cultivation, commercialization and consumption to secure benefits for local populations. Here, we explore some approaches to identifying priority species, assessing constraints and promoting the use of NUS.

Identification of priority species

To improve nutrition, development efforts should focus on locally available NUS from under-consumed food groups. Nutritional needs and the seasonal dynamics of hunger in focal communities and regions must be considered and an inventory should be made of locally available crops (wild and cultivated) that could fill these nutritional gaps. If information on local diet quality is not already available, assessments of micronutrient intakes can be undertaken using quantitative dietary recall (Gibson and Ferguson, 2008). A lighter-touch approach to identifying under-consumed food groups is qualitative 24-hour recall (for example, dietary diversity score) (FAO and FHI 360, 2016) or focus-group discussions (such as four-cell analysis) (Raneri et al., 2017).

Assessing the seasonal availability of foods can help identify those species available at specific times of the year when dietary gaps are heightened due to lack of access to nutritious foods. The prioritization of crops should also take into account tolerance to marginal soils or climate stress, local food preferences and cultural values, and market opportunities. Information on the beneficial properties of NUS can be gleaned from past studies, local experts and community consultations, so as to leverage local knowledge (Padulosi et al. 2019). Including older men and women in the consultation process can help to identify foods that were used in the past, but which may be falling out of use among younger generations.

Assessment of bottlenecks and constraints

People may not be using nutritious NUS for a variety of agronomic, social, economic or political reasons. Consultations with producers and consumers, as well as other actors in the value chain, can help identify why this is happening and what measures can be taken to bring these foods back to the table (Will, 2008). Questions that can guide this process include:

- Why do people not consume more of these crops?
- Why do people not market/sell more of these crops?
- Why do people not produce more of these crops?

And, more generally, with regard to the marketing of diverse crops and varieties:

- What are the market conditions under which crop biodiversity can be best promoted?
- How can social marketing be used to promote crop diversity?
- What market-based instruments (such as tax breaks or eco-labelling) or incentives (such as subsidies for purchasing inputs, procurement by government, or cash incentives to farmers) can be used to promote crop diversity in markets and value chains?

Common bottlenecks encountered in NUS promotion include the unavailability of quality seeds, poor agronomic practices, poor yields, the drudgery of harvest and/or post-harvest operations, scant nutritional and marketing information, a lack of primary processing equipment, disorganized or non-existent value chains, a lack of knowledge about nutrition or health benefits, insufficient or unenticing preparation methods, a lack of knowledge about possible climate change, pest and/or resilience benefits, and "poor man's food" perception, especially among young people (Padulosi et al., 2014).

Interventions to enhance NUS uptake

Rural advisory services can play an important role in tackling bottlenecks to enhance the use of nutritious NUS, for example, by providing quality seeds and advising on improved cultivation practices and technologies. To enhance the consumption of these species, advisory services can team up with health extension workers to improve knowledge of nutritional content and the benefits

of different species to diets, best practices to reduce spoilage, rotting or the contamination of foods, and how to prepare foods in interesting and desirable ways through community cooking sessions.

To improve the commercialization of NUS, advisory services can support the formation of alliances among growers and value-chain actors, such as farmers' associations, cooperatives and multi-stakeholder platforms. As NUS tend to have multiple bottlenecks at many steps of the chain, from seed availability and production to processing, value-chain organization and consumer demand, the best results will be achieved when several bottlenecks are targeted simultaneously (King et al., 2009; 2013; 2015; Padulosi et al., 2015).

Capacity-building and collaboration

Rural advisory services (including agricultural and health extension services) require a broad set of skills and knowledge to promote cultivation, commercialization and the consumption of nutritious NUS. Collaboration between agricultural extension and rural health services can be the most effective method of promoting these crops in diets and production systems. Training in agronomy and value-chain management is a good base for extension agents to assess the main constraints on production, processing, and marketing of these species. Familiarity with the wild and semi-domesticated plants in the local environment will assist with the identification of priority species.

Likewise, an understanding of local diets and nutrition issues in target populations will support the prioritization process. Sensitization to local consumption preferences and perceptions, and learning how to engage with farmers to collect this type of information, are important to the comprehension of demand-side issues. The capacity to recognize important actors in the value chain and rural advisory-service system, as well as a proactive attitude to reach out to engage these actors to help in overcoming bottlenecks, will help to advance the use of these nutritious species (Gruère et al., 2009; King et al., 2018).

Costs

The costs associated with species prioritization and the identification of bottlenecks are largely associated with the staffing required for background research, workshops and field visits for community and multi-stakeholder consultations. The cost of enhancing the use of NUS will depend on the nature of the interventions involved (for example, equipment, training and personnel). Wider use of NUS has the potential to decrease the cost of a nutritious diet for the people involved, however, the costs in terms of time and burden (particularly for women) to collect and process the food should be taken into account.

EVIDENCE OF IMPACT, SUSTAINABILITY AND SCALABILITY

NUS can support better diet quality for local communities (Rowland et al., 2015) and their value-chain development can enrich rural food environments by improving consumers' direct access to nutritious foods and by generating income that can be allocated to the purchase of other nutritious foods. The impact of NUS can be also seen in terms of improved sustainability, the reduced use of inputs, and the greater resilience of food systems in periods of shock. NUS may not become multi-million-dollar commodity crops, but they can realistically establish themselves as niche crops at district, national or international level, improving direct access to nutritious foods for community consumption and generating sustainable income to support local farmers and other value-chain actors involved in their promotion (see, for example, Pallante et al., 2016).

Although thorough, large-scale studies to assess such an impact are still lacking, success in promoting minor millets in India provides some examples of how NUS can be leveraged to enhance local livelihoods (see Box 3). It is very revealing that the Indian Government has included minor millets in the national public distribution system in recognition of their strategic role in the country's nutrition security, creating an unprecedented opportunity for their wider consumption (Padulosi and King, 2018).

Box 3. NUS CASE STUDIES

Minor millets in India

In the Kolli Hills of the Namakkal district of India, from 2014 to 2016, an estimated 56 tonnes of millet were produced by 759 local farming families from 45 settlements. It was used for home consumption, stored as seed or sold. The secret to the families' success is the Agrobiodiversity Conservers' Federation, a registered society involved in managing minor millets from farm to fork. The Federation's current membership stands at 1 511 members from 47 self-help groups and 62 farmers' clubs that specialise in different areas, from production and processing to value addition and distribution.

The initiative has been built up over time; it started in 1997 with 10 self-help groups and was institutionalised in 2009. Mechanised mills have reduced the drudgery of processing millet grains. Women used to spend up to an hour manually processing one kilogram of grain and now it takes just five minutes. Food fairs, innovative recipes and the successful marketing of value-added millet products have increased the amount of millet consumed across the region as a part of a diverse meal (for more, please see Mondal et al., 2016; King and Padulosi, 2017).

Chaya in Guatemala

Chaya (*Cnidoscolus aconitifolius)*, also known as Mayan spinach, is an evergreen hardy shrub, domesticated by the Mesoamerican peoples in pre-Columbian times. It is typically cultivated on a small scale in gardens and on field margins for household use. Chaya contains far higher amounts of several macro- and micronutrients than other dark green leafy vegetables, including protein (60g per 1kg of leaves), vitamin A, niacin and vitamin C. Within the framework of the International Fund for Agricultural Development European Union (IFAD-EU) NUS project, bottlenecks hindering its wider use in Guatemala were identified along the chaya value chain (Bioversity International, 2015).

Among other things, the study revealed that: (1) small-scale chaya marketing exists (within the Dry Corridor, which stretches from Southern Mexico to Panama and suffers from severe inclement weather due to El Niño), whereby farmers directly sell to consumers, or vendors; (2) companies produce nutraceutical chaya-based products for export, with a few in-country sales points targeting affluent consumers; and (3) low demand is a major limiting factor. The major barriers to demand were found to be low consumer awareness of the crop's existence or its nutritional benefits, the perception of the crop as a "poor man's food", limited recipes, and the fact that when households did consume Chaya, it was usually sourced from their own garden. Low market value, little profitability and inconsistent availability were other challenges that emerged from the value-chain assessment.

There were several interventions to promote chaya in the Dry Corridor of Guatemala, where farming communities face severe food insecurity and malnutrition, with conditions exacerbated by climate change. More than 16 700 cuttings of chaya were disseminated to farmers for planting in home gardens and communal nurseries, accompanied by training on how best to cultivate and propagate it. A women-led cooperative was established, linking local producers with small businesses, chefs and restaurants in Guatemala City. Women were trained in various processing techniques, including protein extraction and leaf drying using solar ovens, and in novel recipes developed by local chefs. Active engagement with local government led to the successful introduction of chaya, sourced from local farmers, into school feeding programmes. Recipe books, tasting samples and nutritional information were disseminated in local markets in Chiquimula to help popularize the crop. (For more on Bioversity's work on chaya, please see Bioversity International, 2018).

DISCUSSION

NUS that are nutritious, climate-resilient, economically viable and culturally important have great potential to support agricultural diversification and create synergies between strategies aimed at improving diet quality and climate-change resilience (Baldermann et al., 2016). Enhancing the use of NUS can be a cost-effective and culturally appropriate means of improving the resilience of local food systems and farming-household incomes and nutrition by increasing the diversity of nutritious foods available in rural food environments, often as a low-cost option for the rural poor most in need of better nutrition and diets.

However, there are numerous challenges and limitations being faced by smallholder farmers, who are the guardians of this local agrobiodiversity, which limit the potential for NUS to have a greater impact on the wider food environment.

Large-scale farming systems prioritize efficiency and, as there has been little investment in NUS R&D, there are often limitations when it comes to large-scale food-distribution value chains, such as how to maintain the quality and freshness of NUS during transportation or how to make processing methods more efficient. The exponential growth of large-scale and intensified farming systems has seen a prioritization of few commodity crops, in which there has been extensive R&D. The result has been the simplification of global production systems, which has ultimately decreased the diversity of foods available in our food environments and, hence, our diets.

As retail modernization continues to transform food environments through transitioning food systems, rural areas are faced with increasing exposure to more processed and industrialized foods, often replacing traditional NUS, which have become unfashionable in comparison. Policies and incentives need to be put in place to create an enabling environment that values nutritious NUS production by both the large-scale and smallholder farming operations that supply the food companies that use these foods, both in their fresh form as well as in innovative food formulations, to increase demand across the wider food environment, especially in cities. Boosting demand for NUS and NUS-based products in both urban and rural food environments will stimulate production and wider availability.

This article provides insights into how to integrate nutritious NUS into agricultural initiatives. Data generated from the implementation of these projects have a circular effect: the more investment made in NUS, the more information is generated on their potential to improve food security, nutrition, income and food-system resilience.

By the very nature of their definition, NUS are undervalued by the scientific community and, as such, there are often limited data available on their micronutrient content (Burlingame et al., 2009). Many countries are now developing specific food composition tables for NUS (Brazil, for instance) and FAO INFOODS offers a rich source of information through its Food Composition Database for Biodiversity (BioFoodComp4.0) (FAO, 2017). In cases where micronutrient content is unknown, it can be estimated based on a similar food or categorized according to the common nutritional traits of its food-group characteristics (for example, dark green leafy vegetable which can contain iron and vitamin A).

Local and scientific knowledge of prioritized species is essential, as some may have toxic or anti-nutrient properties and must be consumed in small amounts or processed in special ways to reduce toxin content. The promotion of wild species should also be undertaken with care to avoid over-harvesting; domestication can be promoted to overcome that risk.

Importantly, though, the locally available biodiversity may not be sufficient to address all issues related to poor diet quality and nutrition. Combining them with other approaches, including the introduction of nutritious species from elsewhere, may be required to plug some nutrition gaps.

CONCLUSIONS

This NUS approach is well suited to rural communities that manage and live in areas with high levels of biodiversity, especially indigenous peoples. NUS can be integrated into existing extension programmes that focus on commodity species, to improve the diversity and quality of foods available in rural food environments – both directly to households through self-production and through local market and retail outlets. NUS fruit and vegetables, for example, should be considered in any project aimed at increasing the availability and marketing of major staples.

To help extension agents integrate a nutritious NUS approach into existing programmes, supportive national and local policies are needed that recognize these species' value in improving the diversity of nutritious foods available in rural food environments – and hence rural diets and nutrition and the quality and resilience of rural livelihoods (King et al., 2017). It is equally important, however, that we encourage large-scale private-sector investment in NUS production, utilization in food formulation and marketing in modern retail outlets, including supermarkets. Public and private policies should ideally allocate specific funding and provide programmatic support for NUS development (Notaro et al., 2017). There are numerous opportunities to include nutritious NUS in school feeding programmes, tourism initiatives and national procurement programmes, all of which would help to fuel consumer demand for these resources.

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Annex 1. EXAMPLES OF NUS FROM AROUND THE WORLD, WITH VARYING LEVELS OF USE AND MARKETING

The Americas

Latin name	Common name	Family	Notes
Chenopodium quinoa *Amaranthus caudatus* *Chenopodium pallidicaule*	Quinoa Cañahua or cañihua Amaranth	*Chenopodiaceae* *Chenopodiaceae* *Amaranthaceae*	These pseudo-cereals, originating from the Andes, are very hardy and rich in protein. Out of the three, quinoa is on its way to becoming a global commodity after a major promotional campaign carried out by the United Nations in 2013. A tolerance to low temperatures (found in canahua, not in quinoa) has become a precious trait for local farmers contending with early frost due to climate change.
Opuntia ficus indica	Prickly pear	*Cactaceae*	Use of this drought-resistant, juicy fruit and vegetable from central America is becoming increasingly popular in drought-prone regions of the world, where it is used also for fodder and fencing purposes.
Hylocereus undatus	Dragon fruit (pitaya)	*Cactaceae*	This delicious fruit is now being exported to Europe and cultivated in greenhouses in Israel's desert regions. One increasingly popular use is in ice-cream manufacturing.
Bactris gasipaes	Peach palm	*Arecaceae*	The peach palm's fruit is used in many food preparations (sweet and savoury). Palm hearts are extracted from the trees and are seeing a rapid rise in demand around the world. There is a risk of the genetic erosion of species such as the acai palm, *Euterpe oleracea*, but the peach palm grows rapidly, which should help to offset this erosion if promoted.

Africa

Latin name	Common name	Family	Notes
Vigna subterranea	Bambara groundnut	*Leguminosae*	The Bambara groundnut is a good source of protein and highly resilient to drought conditions. Still, the species is at the margin of agricultural production in most African countries. It is being increasingly commercialized as a canned food in a few countries, such as Ghana and South Africa.
Digitaria exilis	Fonio	*Gramineae*	Fonio is a very small cereal grown in the Sahelian countries, but is a champion when it comes to drought resistance. The cereal has a good nutritional profile, including high values of zinc and iron, compared with rice. Yet, it is a species in which there has been little R&D investment.
Cleome gynandra	African cabbage	*Cleomaceae*	One of the most popular leafy vegetables in the region, African cabbage, is almost unknown elsewhere. The leaves are very rich in beta-carotene, folic acid, ascorbic acid, calcium and other important micronutrients. It is only over the past 20 years or so that this nutritious food has commanded attention in formal markets and supermarkets (in Kenya and Tanzania, for example), thanks to promotional campaigns.
Corchorus olitorius	Jute mallow	*Malvaceae*	Fresh leaves and young fruits are used as a vegetable, the dried leaves are used for tea and as a soup thickener. It is highly popular in Egypt as an ingredient in a popular soup, but far less so in other sub-Saharan countries, where its resilience and high nutrition profile could be most beneficial to farmers and consumers.
Solenostemon rotundifolius	Frafra potato	*Lamiaceae*	Its tasty tubers are eaten as a relish with a starchy staple food. It has seen a recent decline in consumption, making it a food rarity, but is still cultivated in some West African countries and in South Africa. Its ability to grow in dryland regions characterized by poor soils makes it an ideal option as a crop for coping with climate change.

Europe

Latin name	Common name	Family	Notes
Eruca sativa *Diplotaxis tenuifolia* *Diplotaxis muralis*	Rocket	*Brassicaceae*	A spicy leafy vegetable from the Mediterranean, which has become an almost indispensable ingredient in salads in Europe, Australia and North America, but is as yet unknown in many other regions of the world.
Triticum monococcum *Triticum dicoccum* *Triticum spelta*	Hulled wheats: Einkorn Emmer Spelt	*Graminaeae*	Once the wheats used by the Pharaohs, einkorn is today a relic species. Emmer and spelt have been promoted in Italy over the past 20 years and are much sought after as specialty foods today; their hardiness and ability to grow in poor soils (a feature appreciated by the Romans) could be leveraged for cultivating cereals in stressful conditions.
Cydonia oblonga	Quince	*Rosaceae*	Intercropped in small quantities in mixed orchards with apples and other fruit trees, the quince fruit is appreciated for its intense aroma, flavour and tartness. It is commonly used in stews (in the Middle East) or in jams, marmalades and sweets.
Ceratonia siliqua	Carob	*Leguminoseae*	Its dried, toasted pods are often used as a cocoa substitute in carob bars, sold in health-food stores. Owing to its drought resistance, it is well adapted to the conditions of the Mediterranean region and could be better valued in areas characterized by poor soils.
Artemisia dracunculus	Tarragon	*Asteraceae*	Appreciated for their flavour, tarragon leaves are a common herb in French cookery. However, they are also consumed fresh as an appetizer in some countries (in Syria, for example) and added to traditional dishes in countries such as Iran and Slovenia.

Asia-Pacific

Latin name	Common name	Family	Notes
Moringa oleifera	Moringa	*Moringaceae*	A shrub, native to the Himalayas but used across Asia, its leaves are increasingly being promoted around the globe as a nutraceutical and food supplement due to their high content of vitamin A, vitamin C, iron, calcium and protein.
Setaria italica *Panicum miliaceum* *Eleusine coracana* *Paspalum scrobiculatum* *Panicum sumatrense* *Echinochloa colona*	Foxtail millet Proso millet Finger millet Kodo millet Little millet Barnyard millet	*Gramineae*	Known as minor millets, and more recently termed nutri-cereals, these species are very rich in minerals (such as iron and calcium) and other micronutrients (folic acid, for example). They are resilient and hardy crops and can grow in tough conditions. Because of these traits, they were recently listed in India's Food Security Act and included in its public distribution system, along with wheat and rice, which should prove a major breakthrough in terms of their popular use in the country.
Colocasia esculenta	Taro	*Araceae*	Taro is a versatile plant that is primarily used for its roots, but also its leaves and flowers. The hardy tropical plant is both cultivated and harvested in the wild and is often an important source of nutrients in lean times.
Basella rubra	Malabar spinach	*Basellaceae*	Consumed in tropical Asia and Africa as a leafy vegetable, it is a fast-growing plant, with semi-succulent, heart-shaped leaves, rich in vitamins A and C and calcium. It is often used in stir-fries and to thicken soups.
Eleagnus angustifolia	Russian olives	*Elaeagnaceae*	A hardy shrub native to west and central Asia with sweet edible fruit, the Russian olive plant can store nitrogen in its roots, allowing it to thrive in poor soils with bare mineral substrate.
Phyllanthus emblica	Amla	*Phyllanthaceae*	Its edible fruits are very rich in vitamin C and widely used to in pickling with salt, oil and spices. It is also consumed fresh and in the preparation of various dishes, including sweets, made by soaking the berries in sugar syrup.
Canarium ovatum	Pili nut	*Burseraceae*	A tropical tree, it produces nuts with kernels of a similar flavour to pumpkin seeds and, when roasted, pine nuts. The kernels are also used in chocolate, ice-cream and baked goods, while its young shoots and fruit pulp are used in salads and other dishes.

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