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REVIEW

The potential of neglected and underutilized species for improving diets and nutrition

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Abstract

Main conclusion **Nutrient-rich neglected and underutilized plant species could help transform food systems, provided science and policy are better connected, and greater coordination exists among the diverse stakeholders working with these species.**

Abstract Why have our food systems come to rely on such a narrow range of plant species of limited nutritional value? Today three staple crops (rice, maize and wheat) account for more than 50% of calories consumed while we continue to disregard the huge diversity of nutrient-rich plant species utilized by humanity throughout our history. The reasons for this situation are complex and challenging. Creative approaches are required to ensure greater integration of these plant species in agriculture and food systems, and ultimately greater food diversity on our plates and in our diets. This paper presents an overview of the nutritional value of select neglected and underutilized species (NUS) before describing in detail the work undertaken in four mega-diverse countries—Brazil, Kenya, Sri Lanka and Turkey—to increase the knowledge, appreciation, awareness and utilization of this nutrient-rich biodiversity encompassing both orphan crops and wild edible plant species. The paper highlights the novel and ingenious approaches these countries have used to prioritize a rich diversity of NUS for healthier diets and improved nutrition, and how this knowledge has been used to mainstream these plant species into production and consumption systems, including linking NUS to school meals and public food procurement, dietary guidelines and sustainable gastronomy. The paper concludes with some perspectives on the way forward for NUS and the community working on them (including researchers, universities and government agencies, national ministries, municipalities, producers, and civil society) in meeting the challenges of malnutrition and environmental sustainability in the 2030 sustainable development context.

Keywords Orphan crops · Neglected and underutilized species · Wild edibles · Biodiversity · Food composition · Nutrition · Policy

Introduction

Mainstream agricultural and food production systems are clearly failing nutrition and the environment (Caron et al. 2018; KC et al. 2018; Willett et al. 2019). One of the monumental challenges currently facing humanity is how to secure universal access to sufficient, nutritious, healthy and affordable food that is produced in a sustainable manner (Bioversity International, 2017). While the proportion of people who are hungry on our planet has halved since the early days of the Green Revolution, trends in hunger and food insecurity consistently reveal a situation in which populations remain poorly nourished. At the same time, modern food production systems are shown to contribute significantly to major environmental issues, including biodiversity loss, greenhouse gas emissions, contamination and shortages of water, ecosystems pollution, and land degradation

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(Willett et al. 2019). A recent review by Springmann et al. (2018) on the environmental impacts of food systems shows that failure to apply targeted mitigation measures in agricultural production systems will ultimately result in a 50–90% increase in global environmental pressures and a destabilization of key ecosystem processes. The study concluded that a shift towards healthier diets alone could reduce greenhouse gas emissions and other environmental impacts by 29% and 5–9%, respectively, while the adoption of plant-based diets increased these percentages to 56% and 6–22%, respectively. These figures further support our conviction that a food systems transformation is required to move beyond producing more food towards finding ways “to nourish everyone in ways that can be sustained environmentally, economically and culturally” (Haddad et al. 2016, p. 32).

In 2017, the number of undernourished people increased to 821 million, signaling a rise in world hunger and a reversal of trends following a prolonged decline (FAO, Ifad, UNICEF, WFP, WHO 2018). Child stunting remains unacceptably high with approximately 151 million children affected and 51 million children wasted. About 2 billion people lack the key micronutrients they need for physical and mental development such as iron and vitamin A (Development Initiatives 2017); more than one in eight adults are obese—over 672 million people worldwide—(FAO, Ifad, UNICEF, WFP, WHO 2018), while three out of four deaths are caused by non-communicable, diet-related diseases (e.g., diabetes, hypertension), particularly in emerging economies and in low-to-middle income countries (Forouzanfar et al. 2015; WHO 2017). Extremes such as stunting in children and overweight in adults are occurring concurrently while countries that experience multiple forms of malnutrition are increasingly common (Haddad et al. 2016).

A principal cause of the multiple burdens of malnutrition is poor diet. Current food systems produce large quantities of food, but not enough of the required nutrient-rich, plant-based foods needed for healthier and sustainable diets (Siegel et al. 2014; Willett et al. 2019). A study of global food supplies by Khoury et al. (2014) illustrates the homogenization of global diets, showing a 68.8% decrease in variation between food supplies in different countries. In 48 years, from 1961 to 2009, diets worldwide have become increasingly similar, dominated by wheat, rice, and maize at the expense of alternative staples such as sorghum, millets, rye, cassava, sweet potato, and yam. Adjectives such as ‘underutilized’, ‘neglected’, ‘orphan’, ‘minor’, ‘promising’, ‘niche’, ‘local’ and ‘traditional’ are often used to define these species, which have been marginalized by specialized modern agricultural production systems.

This paper focuses on these underutilized nutrient-dense varieties of fruits, vegetables, nuts, roots and tubers, pulses, grains and food trees that hold significant potential for improving diets and nutrition, while protecting biodiversity in agricultural landscapes and food systems (Bioversity International 2017; Fanzo 2019). These domesticated, semi-domesticated, or wild species and varieties are referred to in this paper as “neglected and underutilized species” (NUS) and are defined as: “useful plant species which are marginalized, if not entirely ignored, by researchers, breeders and policy makers” (Padulosi et al. 2013).

The exact number of NUS we can rely on to support biodiversity-enhancing and nutritious food production systems is still uncertain given there is no scientific consensus on the total number of edible plant species in existence. Reports vary dramatically: from 12,500 reported in Kunkel’s checklist on edible species (1984), to 27,000 in Rapoport and Drausal’s review (2001), who suggest that for any given environment or biota, a minimum of 10% of species are expected to be edible. 75,000 are reported by Wilson (1988) who further infers that much of this diversity is “superior to the crop plants in widest use”. William and Haq (2002) claim that over 7,000 either partly of fully domesticated plant species have been used for food at some point in human history. More conservative estimates by the Royal Botanic Gardens Kew (2016) mention 5538 plant species that provide human food, but no indication is given regarding the species’ provenance (whether domesticated or wild). More recently, Meldrum et al. (2018) identified 1097 vegetable species that could be used to diversify agricultural systems for improved nutrition based on a review of the Mansfeld Encyclopedia of Agricultural and Horticultural Plants. Knowledge gaps remain for other food groups such as fruits, cereals, pulses and roots and tubers.

Wild edible plant species, which may be harvested from cultivated production systems or from natural or semi-natural ecosystems, also play a large role in diversifying diets, particularly in local food systems. In the recent State of the World’s report on Biodiversity for Food and Agriculture (FAO 2019), 15 of the 91 reporting countries (16%) give details of regular use of wild foods in their national diets. Ethiopia, for example, reports that 30–40% of its population consumes wild plant species on a regular basis, with the percentage increasing to 56–67% in specific regions. In other countries, wild foods are used as supplementary food sources in times of food scarcity or are used during cultural and religious festivals (CGRFA 1997). Again, the exact number of wild edible plant species eludes us.

This paper focuses on the nutrition potential of NUS, which, although under-researched, frequently have superior nutrition content compared to the crops currently dominating our food systems (Kobori and Rodriguez-Amaya 2008; Bharucha and Pretty 2010). This paper indicates that these species and the genetic diversity they contain hold great potential for food and nutritional security, as well as for combating the ‘hidden hunger’ caused by micronutrient (vitamin and mineral) deficiencies (Padulosi et al. 2013).

With regard to nutritional value, data suggest high levels of inter- and intra-specific diversity within NUS (Burlingame et al. 2009). This evidence is taken increasingly into consideration by new food-based dietary guidelines—such as the Dietary Guidelines for the Brazilian Population (Ministry of Health of Brazil, 2015) (Fig. 9)—that advise people to consume a diverse range of species and different varieties of the same species to improve diet quality.

These underutilized and underappreciated resources come with additional multiple benefits. They are strongly linked to the biocultural heritage of their places of origin (Bharucha and Pretty 2010); they are highly adapted to marginal, complex and difficult environments and have contributed significantly to diversification and resilience of agroecological niches; they may be collected from the wild or grown in traditional production systems with little or no external inputs (Padulosi et al. 2011); and could contribute to improved incomes (Moraza et al. 2018).

Even the most conservative estimate of 5000 NUS can be a daunting number to consider when it comes to thinking about how to utilize these resources to diversify food systems for healthier, diverse diets. Equally challenging is understanding the implications for mainstreaming[1] this diversity and bringing this approach to scale. With such a diversity of species, these can be disconcerting numbers and questions for a national policy or decision-maker to deal with, especially when faced with food systems that have so many seemingly insurmountable barriers to diversification and 'lock-ins' keeping current systems entrenched and intransigent to change (IPES-Food 2016): these include the expansion of specialized modern agricultural production systems, the neglect of NUS by international research and development (Meldrum et al. 2018), and numerous barriers to their integration into modern agricultural production systems (Hunter and Fanzo 2013).

Fortunately, many countries, especially in biodiversity hotspots, maintain nutrient-rich NUS for a variety of purposes. Custodians, including smallholder farmers, pastoralists, forest dwellers and various indigenous and local communities maintain these plant species for culture, food security and resilience. At the same time, many of these crops and varieties threatened with loss have been collected and conserved in genebanks and are available for use by researchers and breeders, which will be increasingly important as we shift away from traditional selection criteria and focus on nutritional value of crops rather than higher agronomic yields (FAO 2010). It is the aim of this paper to demonstrate novel ways to shift the center of gravity in food systems towards one that is more diversified, sustainable and beneficial for human nutrition and the environment. This paper describes a multi-sectoral approach that has been piloted in four mega-diverse countries—Brazil, Kenya, Sri Lanka and Turkey—to assess the broad range of diversity of NUS present at the national level, and to identify and prioritize these to a smaller, more manageable number with the highest potential for contributing to healthier diets and improved nutrition. It will demonstrate the nutritional value of a select group of NUS, and provide examples of innovative approaches used to mainstream NUS into production and consumption systems at multiple scales, from local, national to global, while preventing over-exploitation of these resources. The paper concludes with some perspectives on the way forward for NUS and the community working on them in meeting the challenges of malnutrition and environmental sustainability in the 2030 sustainable development context.

The nutritional value of neglected and underutilized species

Neglected and underutilized species (NUS) provide valuable macronutrients such as carbohydrates, proteins and fats, micronutrients such as vitamins and minerals, as well as bioactive non-nutrients that contribute to dietary health (Toledo and Burlingame 2006; Blasbalg et al. 2011; Fanzo et al. 2013; Dulloo et al. 2014; WHO/CBD 2015; Bioversity International 2017). This food diversity represents a natural wealth for many countries yet most, if not all, fail to use them adequately for this purpose.

As previously emphasized, the contribution of NUS to healthy and diverse diets can occur at the species level as well as at the level of diversity within a species. Many food composition researchers recognize that nutrient content differences among varieties of the same species can be greater than the differences between species (WHO/CBD 2015). Unfortunately, most research has left this varietal level largely unexplored. Nutrition science generally considers the diversity of diets only in regard to inter-species diversity, while food composition data have largely been limited to an aggregate level, often ignoring the significant compositional differences related to agroecological zone, seasonality and, most importantly, genetic diversity.

The scientific literature reports intraspecific differences in the nutrient content of many plant-based foods, which

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[1] Mainstreaming refers to the integration or inclusion of actions related to the conservation and sustainable use of biodiversity into sectoral strategies, plans and programmes relating to production sectors, such as agriculture, fisheries, forestry and tourism. Mainstreaming also refers to the inclusion of biodiversity considerations into poverty reduction plans and national sustainable development plans. Decision XIII/3, Conference of the Parties to the Convention on Biological Diversity.

are often nutritionally significant (FAO/INFOODS 2013).[2] Research from the Pacific demonstrates that traditional varieties of locally important species (bananas, pandanus, breadfruit, taro, yams) often have a higher nutrient profile than more commonly consumed varieties that dominate the marketplace (Englberger and Johnson 2013). Yet many of these nutrient-rich traditional varieties have become neglected for a variety of socio-economic or political reasons. In the case of some local banana varieties, the pro-vitamin A carotenoid content ranged from as little as 1 µg to as much as 8500 µg per 100 g, more than a 1000-fold greater than the common Cavendish variety bananas (Englberger et al. 2003a, b). Considerable variety specific differences in carotenoid content have also been recorded for sweet potato by Huang et al. (1999) where cultivars vary in carotenoid content by a factor of 200 or more. In Papua New Guinea, Rubiang-Yalambing et al. (2014) also demonstrate similar varietal specific nutrition differences in aibika (*Abelmoschus manihot* L.), a culturally important leafy green vegetable.

Kobori and Rodriguez-Amaya (2008) have demonstrated higher carotenoid levels of wild native Brazilian leafy green vegetable species compared to commercially produced leafy vegetables. Likewise, Fentahun and Hager (2009) have shown that vitamin C levels in baobab fruits (*Adansonia digitata)* are six times higher than oranges, while McGarry and Shackleton (2009) have shown that *Amaranthus*, a widely used green leafy vegetable, contains 200 times more vitamin A and ten times more iron than the same-sized portion of cabbage. The nutritional and health benefits of a number of the NUS/orphan crops included in this special issue have been demonstrated, including: minor millets (Bhat et al. 2018); teff (Cheng et al. 2017); quinoa (Vega-Gálvez et al. 2010); African leafy vegetables including *Cleome gynandra* (Schönfeldt and Pretorius 2011); horsegram (Bhartiya et al. 2015); buckwheat (Christa and Soral-Śmietana 2008); rice bean (Katoch 2012); enset (Bosha et al. 2016; Daba and Shigeta 2016); underutilized roots and tubers (Olango et al. 2013); and minor fruits (Kehlenbeck et al. 2013).

This evidence represents the tip of iceberg in terms of exploring the genetic diversity and nutritional value of NUS. This is hardly surprising given that the number of NUS is considerable and the cost of nutritional analysis is high. Such species are usually not a priority so research of this nature is piecemeal and sporadic, often project driven. Yet, their inclusion in diets could reduce nutrient deficiencies and offer more local, sustainable and culturally acceptable solutions to problems of malnutrition in many parts of the world.

Shrinking diversity: the many barriers to mainstreaming NUS

The previous section begs the question, if many NUS are so nutritionally valuable and superior to the majority of mainstream crops, why are they not more integrated into our food systems, or why is the diversity in our agriculture, food systems and diets shrinking? Despite increasing awareness of their nutritional value, there remain many barriers (Fig. 1) limiting the integration of NUS into food systems (Fanzo et al. 2013; IPES-Food 2017).

Specialization of crops is not something new; humanity has been selecting crops since the earliest domestications many thousands of years ago. While early hunter-gatherers subsisted on a wide range of wild animal and plant biodiversity, this changed with the domestication of crops and livestock, which happened independently in a number of localitiesaround the world over a relatively short space of time. Out of an estimated 300,000 plant species, approximately 5000 have at one time or another been used for human food (RBG Kew 2016), but only 150–200 have ever been cultivated widely (FAO 2015). Since the Neolithic, ongoing revolutions in production and consumption of food—the agricultural, industrial, chemical, Mendelian genetics, Green and supermarket revolutions, to name a few—each have contributed to the shrinking diversity in agriculture, food systems and diets (Guarino et al. 2016). Contemporary industrial agriculture and modern global food systems have exacerbated the displacement and disappearance of NUS, their genetic diversity and biocultural heritage (IPES-Food 2016) through an over-reliance on crop monocultures of high-yielding, genetically uniform crops (Gollin et al. 2005). Today only 12 crops and 5 animal species provide 75% of the world's food (FAO 2015).

Putting NUS back on the national agenda: lessons from Brazil, Kenya, Sri Lanka and Turkey

It is unclear exactly how much of this diversity has been lost (Guarino et al. 2016) and, given this trajectory, whether it is possible to reverse such a trend in favor of more substantial diversification and integration at various scales. This is the subject of much discourse and debate in the literature (IAASTD 2009; IPES-Food 2016; FAO 2019; Willett et al. 2019) and will not be discussed further in this paper. Rather, the focus is to highlight practical examples and strategic actions taken by a group of pioneer countries to single out—from a bewildering array of NUS—those with high nutritional value and use this knowledge to create an enabling environment to mainstream priority plant species into

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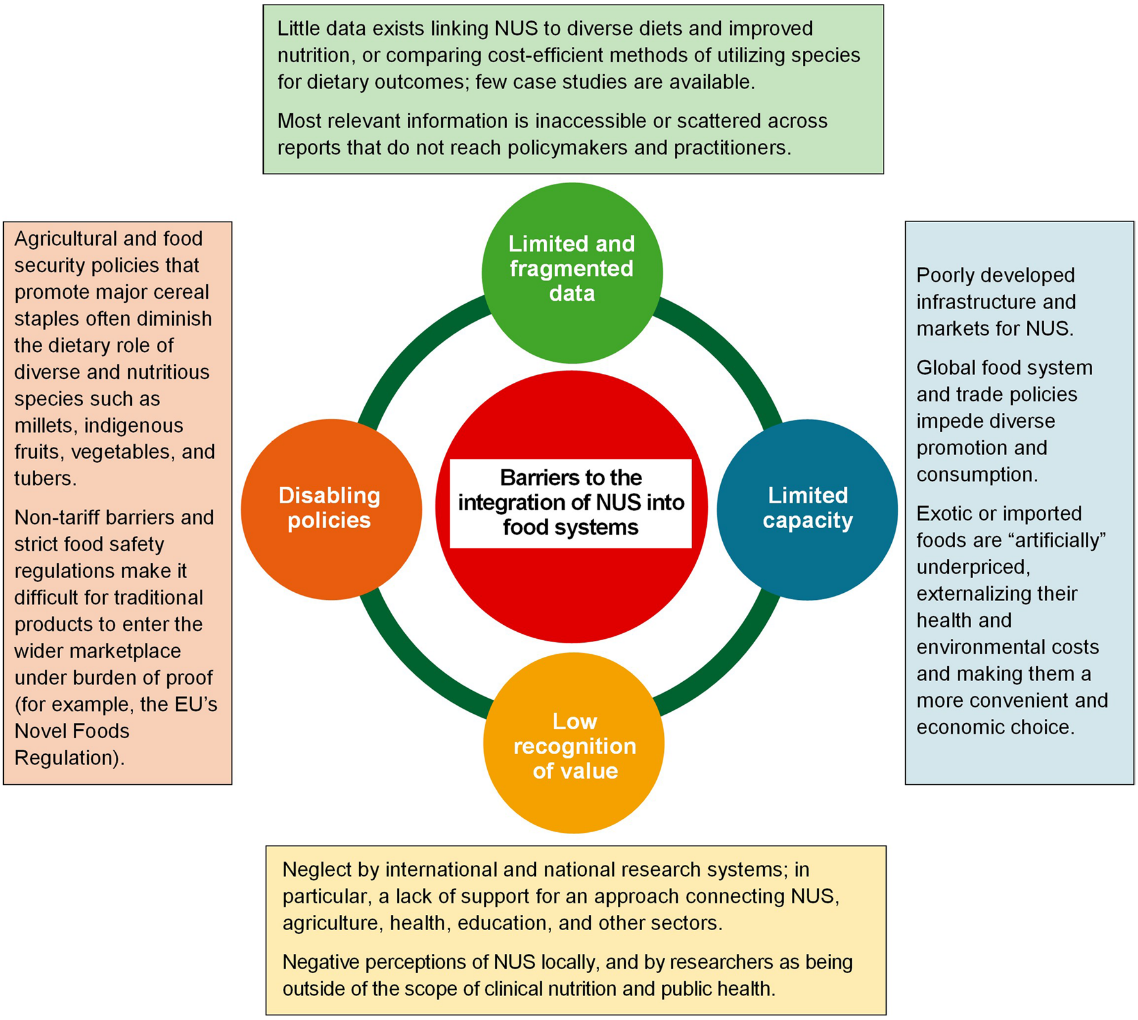
[2] FAO/INFOODS is an International Network of Food Data System monitored by the Food and Agriculture Organization of the United Nations.



Little data exists linking NUS to diverse diets and improved nutrition, or comparing cost-efficient methods of utilizing species for dietary outcomes; few case studies are available.

Most relevant information is inaccessible or scattered across reports that do not reach policymakers and practitioners.

Agricultural and food security policies that promote major cereal staples often diminish the dietary role of diverse and nutritious species such as millets, indigenous fruits, vegetables, and tubers.

Non-tariff barriers and strict food safety regulations make it difficult for traditional products to enter the wider marketplace under burden of proof (for example, the EU's Novel Foods Regulation).

Poorly developed infrastructure and markets for NUS.

Global food system and trade policies impede diverse promotion and consumption.

Exotic or imported foods are "artificially" underpriced, externalizing their health and environmental costs and making them a more convenient and economic choice.

Neglect by international and national research systems; in particular, a lack of support for an approach connecting NUS, agriculture, health, education, and other sectors.

Negative perceptions of NUS locally, and by researchers as being outside of the scope of clinical nutrition and public health.

Fig. 1 Schematic diagram depicting the key barriers to the integration of NUS into food systems

national policies, strategies and plans of action to improve nutrition (Hunter et al. 2016, 2017a, b; Beltrame et al. 2017). As part of the *Mainstreaming Biodiversity Conservation and Sustainable Use for Improved Nutrition and Well-Being* (Biodiversity for Food and Nutrition Project, or BFN for short),[3] Brazil, Turkey, Sri Lanka and Kenya have taken key steps to establish enabling environments to mainstream NUS for improving nutrition by strengthening three interconnected components: knowledge and evidence; policies and governance; and, capacity, partnerships and awareness (Hunter et al. 2016). To avoid over-exploitation, countries also developed sustainable collection and management practices and, where possible, brought wild-harvested species into cultivation.

Improving the knowledge and evidence base recognizes the need for more food composition data on the world's NUS. Compositional data can, and should, play a crucial role in national nutritional planning, recommendations, food processing and breeding programs. This component also identifies the need to apply locally fitting approaches to prioritizing the considerable levels of diversity of NUS that exist so that a more manageable number can be identified and promoted. A further step in this prioritization process will require narrowing down this list to a smaller set of species with greater short or medium-term potential for cultivation, promotion and marketing, which we will refer to in this paper as "target" species.

To prioritize NUS and target species, each country built on pre-existing interest and research networks to strike a

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[3] The BFN Project is a multi-country, multi-partner initiative led by Brazil, Kenya, Sri Lanka and Turkey and funded by the Global Environment Facility. The initiative is coordinated by Bioversity International with implementation support from the UN Environment Programme and the Food and Agriculture Organization of the United Nations. National partners include relevant ministries, the scientific community, non-government organizations, civil society and local communities.

Fig. 2 The species portfolio of the BFN project includes 185 different plant species, all with the potential to contribute important nutrients to healthier local diets. In reading order: cowpea leaves (*Vigna unguiculata*); jatobá (*Hymenaea courbaril*); black bryony (*Dioscorea communis*); sweet potato (*Ipomoea batatas*); wood apple (*Limonia acidissima*); mung bean (*Vigna radiata*); guava (*Psidium guajava*); gundelia (*Gundelia tournefortii*); jute mallow (*Chorchorus olitorius*); rice varieties (*Oryza sativa*); buriti (*Mauritia flexuosa*); murici (*Byrsonima verbascifolia*); taro (*Colocasia esculenta*); marolo (*Annona crassiflora*); centella (*Centella asiatica*); monkey nut (*Anacardium humile*); foxtail lily (*Eremurus spectabilis*); salsify (*Scorzonera cana*); baru (*Dipteryx alata*); glasswort (*Salicornia emericii*); bambara groundnut (*Vigna subterranea*); finger millet (*Eleusine coracana*); jackfruit (*Artocarpus heterophyllus*) and Kukulala yam (*Dioscorea esculenta*). Photo credit: BFN Project and Wikimedia Commons

balance between elements such as regional needs, nutrition, market capacity and potential, and cultural practice. The prioritization process varied from country to country with methods including market surveys, farmer and consumer interviews, and questionnaires. Through a process of national prioritization, the four countries were able to select a total of 185 plant species with nutritional potential. This includes wild and cultivated species of which a collection is shown in Fig. 2. This context-based prioritization process is illustrated by the two different approaches taken in Turkey and Brazil and described below.

In Turkey, where the focus was on wild edibles, the selection of priority species began with rural and urban market surveys across three geographically distinct locations: the Black Sea, Mediterranean and Aegean Regions. Over two thousand questionnaires (2631) were administered to local plant collectors, sellers and consumers leading to the identification of 43 commonly used edible species, including mushrooms and landraces, which were then prioritized for further research. Samples were collected from markets and from the wild, followed by food composition and antioxidant activity analyses (Tuğrul Ay et al. 2017; Ozbek et al. 2017; Tan et al. 2017). A custom-made sustainability index evaluated and ranked each species according to criteria including environmental, economic and food and nutrition sustainability characteristics. Ultimately, this process resulted in the selection of one target species from each of the three geographic locations, namely einkorn wheat (*Triticum monococcum*), golden thistle (*Scolymus hispanicus*) and foxtail lily (*Eremurus spectabilis*), which became the focus of national marketing strategies and awareness-raising activities.

In contrast, Brazil's prioritization process built on the pre-existing research platform established under the national *Plants for the Future* initiative,[4] which identifies, promotes, and increases the market capacity for native Brazilian flora. Working closely with the initiative as well as with several federal universities and research institutes, such as the Brazilian Agricultural Research Corporation (Embrapa),researchers assembled portfolios for species that had previously been identified as nutritious, culturally significant and of potential economic value. As food composition analysis is costly, existing food composition data were initially compiled by carrying out a systematic and quantitative review of secondary data sources available on the Internet, in food composition tables, as well as reports, dissertations, theses and other grey literature. Only then was food composition analysis carried out for species for which data were missing or incomplete and complete data collected for 78 native fruits, vegetables, and other plants. Species that were deemed capable of improving nutrition and farmer livelihoods were prioritized through policy ordinances that facilitated fair pricing, sustainable use, increased market, and further research that could fill research gaps (Beltrame and Hunter 2015; Hunter et al. 2016).

National prioritization committees were established in Kenya (FAO/Government of Kenya 2018) and Sri Lanka bringing together researchers, academics and representatives from the ministries of agriculture, health, and the environment to select traditional NUS that were perceived to play a role in achieving national nutrition targets and in diversifying diets and included: rice, leafy vegetables, roots and tubers, fruits and pulses.

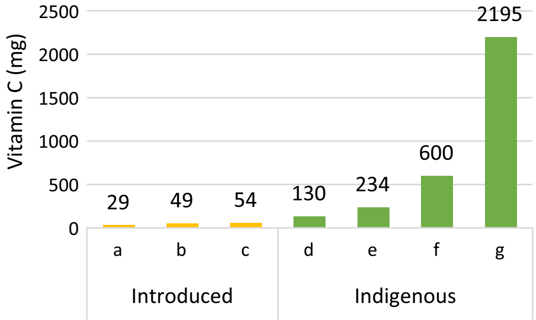

Fig. 3 Vitamin C (mg) in introduced vs. indigenous Brazilian fruits species: **a** lime (*Citrus aurantifolia*); **b** tangerine (*Citrus tangerina*); **c** orange (*Citrus sinensis*); **d** mangaba (*Hancornia speciosa*); **e** white guabiroba (*Campomanesia adamantium*), **f** guabiroba (*Campomanesia xanthocarpa*) and **g** camu camu (*Myrciaria dubia*). Values are expressed per 100 g of fresh raw pulp/whole fruit, with or without peel. Sources: System on Brazilian Biodiversity (SiBBr) and Ministério da Saúde (2015)

In each country, food composition analysis yielded positive results, indicating significantly higher micronutrient content for numerous NUS. When compared to a selection of commonly cultivated crops, a range of locally adapted species were found to have the potential to offset common nutrient deficiencies by supplying larger quantities per serving of vital micronutrients including iron, vitamin C, and calcium. Figures 3, 4, 5, 6 and 7 display a small selection of food composition results from the four countries indicating the range of nutrients available in NUS. Results are shown for target species—both cultivated and wild-harvested—that are currently underutilized but have a place in traditional diets and are recognized for their health value in their respective regions. For example, Fig. 3 compares introduced and indigenous Brazilian fruits, including camu–camu (*Myrciaria dubia*), which contains 40 times more vitamin C than the common orange (*Citrus sinensis*).

Figure 4 represents five species of African leafy vegetables, which are traditionally grown in home gardens or by family farmers in Kenya. When compared to common cabbage (*Brassica oleracea*), a widely consumed vegetable in Kenya, amaranth (*Amaranthus dubius*) is shown to possess nearly 3.5 times as much beta-carotene equivalent, while Malabar spinach (*Basella alba*) has over 13.5 times as much iron. Through direct procurement trials piloted by the BFN project team in Western Kenya, these leafy greens are being introduced into school meals in an effort to reduce undernutrition (UNSCN 2017).

Figures 5, 6 and 7 demonstrate the high levels of inter- and intra-species nutritional diversity in the Turkish

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[4] http://www.mma.gov.br/biodiversidade/conservacao-e-promocao-do-uso-da-diversidade-genetica/plantas-para-o-futuro.html.

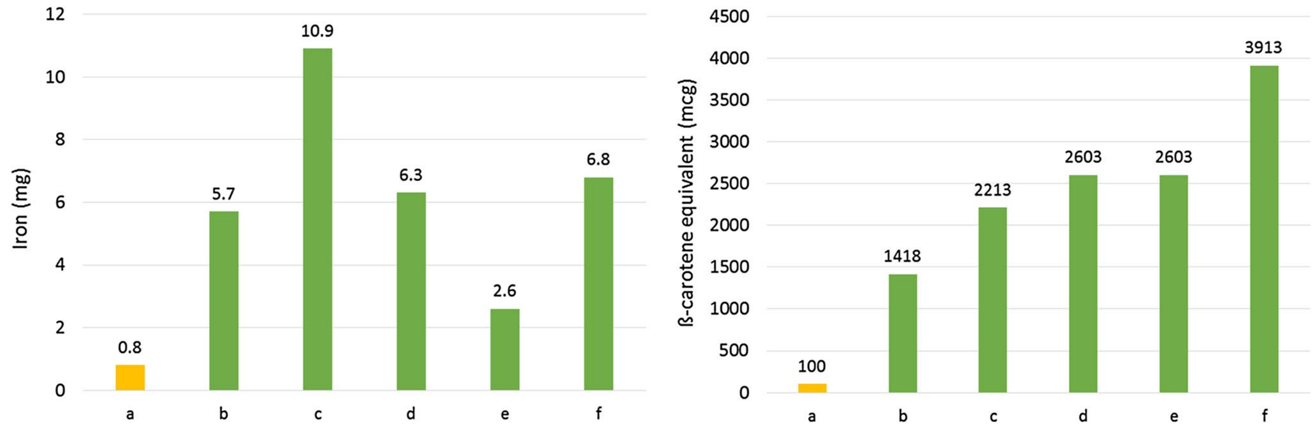

Fig. 4 Five green leafy vegetables with levels of vitamin A (expressed in β-carotene equivalent) and iron content compared to cabbage: **a** cabbage (*Brassica oleracea*); **b** Ethiopian kale (*Brassica carinata*); **c** malabar spinach (*Basella alba*), **d** jute mallow (*Chorchorus olitorius*), **e** spider plant (*Cleome gynandra*), **f** amaranth (*Amaranthus dubius*). Values are expressed per 100 g of fresh, raw vegetables. Sources: BFN Kenya and Staldmayr et al. (2012)

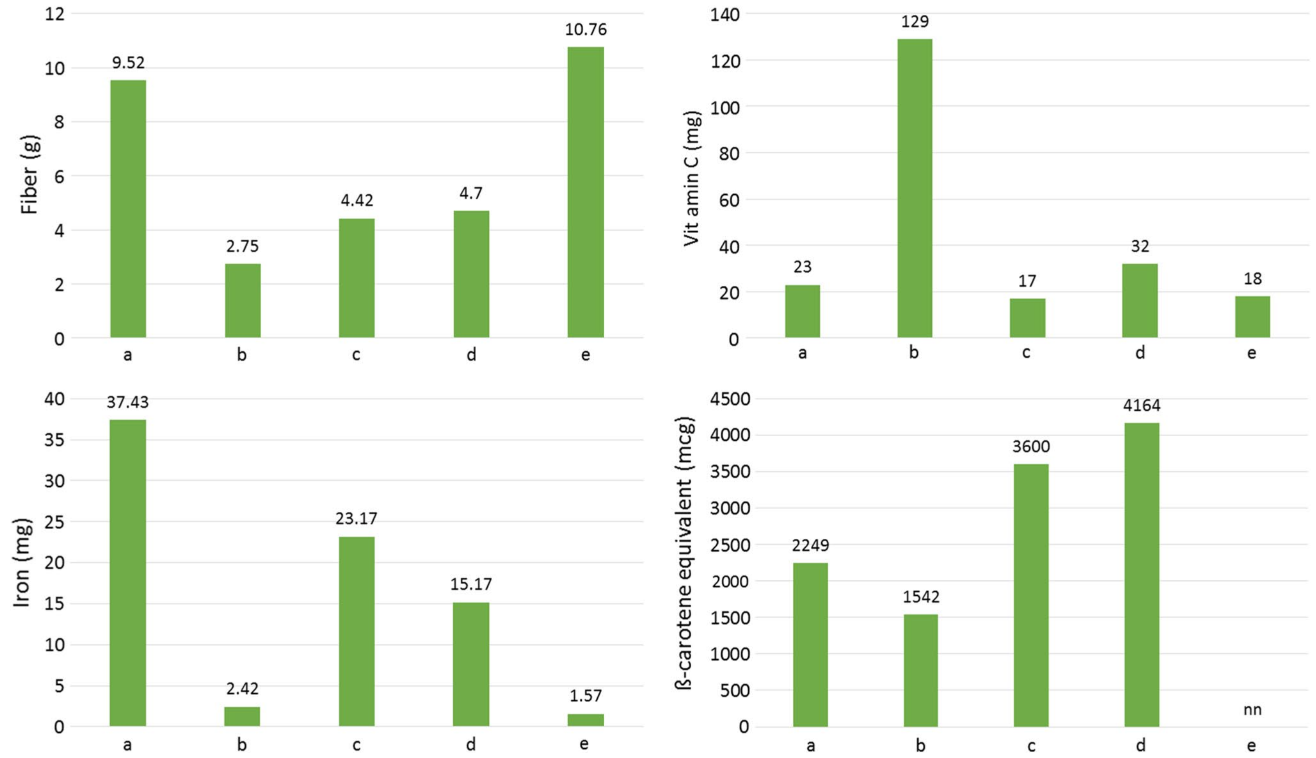

Fig. 5 Fiber, vitamin C, iron, and beta-carotene in wild leafy vegetables in Turkey: **a** Indian knotgrass (*Polygonum cognatum*); **b** foxtail lily (*Eremurus spectabilis*), **c** watercress (*Nasturtium officinale*), **d** purple salsify (*Tragopogon porrifolius* subsp. *longirostris*) and **e** wild fennel (*Ferulago trachycarpa*). Values are expressed per 100 g of fresh, raw vegetables. Sources: TürKomp 2018 (Turkish National Food Composition Database: accessible at http://turkomp.gov.tr/main); FAO/INFOODS database

priorityspecies (Fig. 5), in Sri Lankan native rice varieties (Fig. 6), and in Kenyan and Sri Lankan millets (Fig. 7).

The food composition data compiled thus far in each country have contributed to national information management systems available to researchers, policy makers, development practitioners and others. This includes: the Biodiversity Nutritional Composition Database as part of

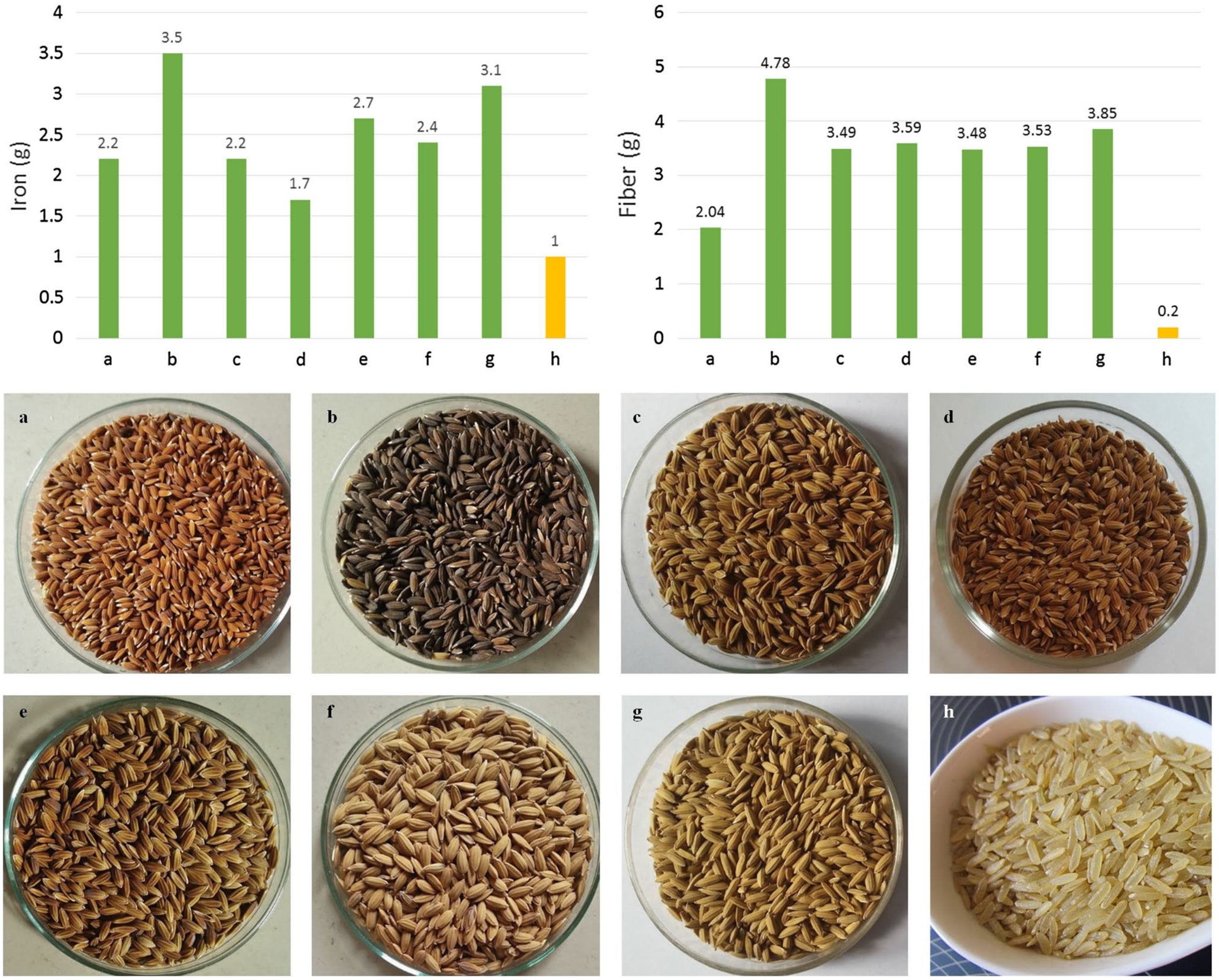

Fig. 6 Comparative iron and fiber content of traditional Sri Lankan rice varieties (*Oryza sativa*): **a** fragrant rice (Suwandel); **b** dark rice (Kalu heenati); **c** red rice (Kurulutuda); **d** red rice (Madathavalu); **e** red rice (Pachchaperuma'l); **f** Pokkali rice; **g** Sudu heenati rice; **h** white rice (milled). Values are expressed per 100 g of raw rice. For local varieties, values were measured after dehulling. Sources: Local varieties: BFN Sri Lanka, White rice (H): Longvah et al. 2017. Photo credit: BFN Project/S. Landersz

the Information System on Brazilian Biodiversity (SiBBr)[5]; a new national portal in Turkey and additions to the Turkish Food Composition database TürKomp, as well as new national portal in Sri Lanka. In Kenya, nutritional analysis of priority species has resulted in the updating of the National Food Composition Tables (FAO/Government of Kenya 2018) that are hosted in the Nutrition Portal of the Ministry of Health. The food composition data generated by the four countries as part of the BFN project are also shared with the global FAO/INFOODS Food Composition Database for Biodiversity and made available to others to use.

Rediscovering NUS: delivering innovative solutions to improve diets and nutrition

A steady flow of high profile reports starkly remind us that our agriculture and food systems are not delivering optimal nutritional outcomes (Global Panel on Agriculture and Food Systems for Nutrition 2016; IPES-Food 2016; HLPE 2017; Willett et al. 2019). Many of these reports draw attention

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[5] The Biodiversity Nutritional Composition Database under the System on Brazilian Biodiversity (SiBBr) is a database is the result of a joint effort of the BFN Project, the Ministry of the Environment and the Ministry of Science, Technology, Innovation and Communications in Brazil. Besides food composition data, the platform also includes a bank of recipes of Brazilian native species. National databases such as the BFN Sri Lanka and BFN Turkey websites also hold nutrition composition information from countries.

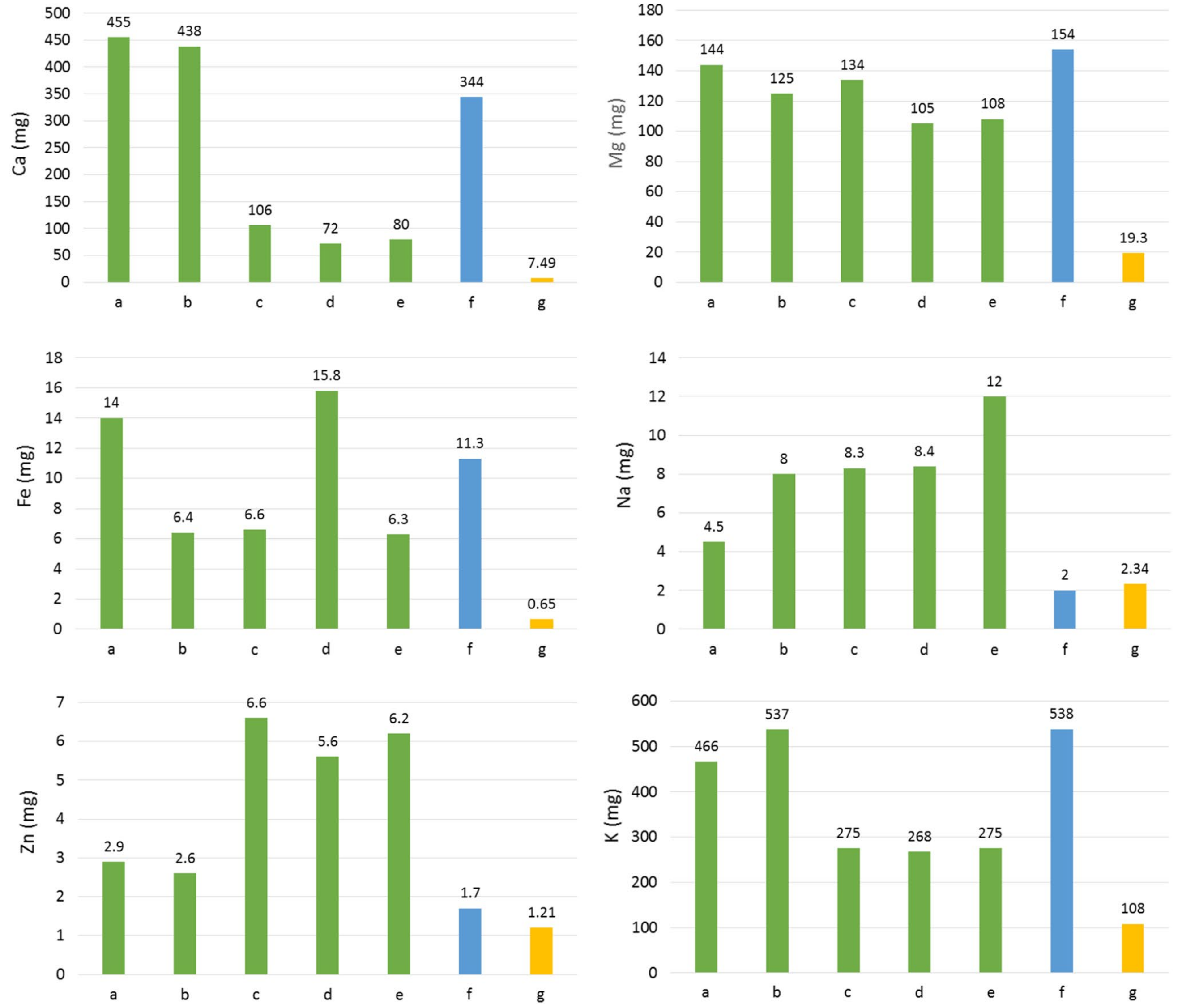

Fig. 7 Diversity in foxtail and finger millet varieties (*Setaria italica* and *Eleusine coracana*) from Kenya and Sri Lanka compared with white rice (milled). Values for calcium, magnesium, iron, sodium, zinc, potassium are given for Kenyan finger millet (blue, on the right of each chart) as well as Sri Lankan varieties of finger and foxtail millets (green): **a** finger millet (Bala kurakkan) (SL); **b** finger millet (Wadimal kurakkan) (SL); **c** foxtail millet (Golden) (SL); **d** foxtail millet (Yellow) (SL); **e** foxtail millet (Black) (SL); **f** finger millet (wimbi) (KE); **g** white rice (milled). Source: BFN Kenya, BFN Sri Lanka and Longvah et al. 2017

to a number of key opportunities and recommendations necessary for the transformation of food systems, some of which provide potential entry points for better utilization of NUS (Kennedy et al. 2017). This includes measures such as sustainable and healthy food sourcing, institutionalizing high-quality diets through public food procurement including food provision in schools, public food procurement to support local agroecological produce, development of short supply chains, development of food-based dietary guidelines linked to local foods and biocultural heritage, and creating policy incentives for diversification and agroecology. However, research to date on NUS has been limited in scope, failing to provide an adequate roadmap for the better integration of NUS into value chains and diets (Mabhaudhi et al. 2017).

One of the main barriers to the effective integration of NUS into modern food production systems, is the disconnect that exists between the agriculture, environment, health and nutrition sectors and the lack of coordination between the many actors that need to be involved. To support the process and drive the effective mainstreaming of agricultural biodiversity for improved nutrition into sector-specific plans, enabling environments need to be created by building capacity and partnerships, and by improving awareness and understanding among the many different stakeholders, which include researchers, universities and government agencies, relevant national ministries, local governments, municipalities, small-scale producers and civil society (Hunter et al. 2016). This section provides examples of how initiators of this process might take advantage of strategic opportunities identified by the BFN participating countries that have already started on this path. It concludes by listing a number of global initiatives that can also help facilitate this transformation.

Mainstreaming NUS for improved diets and nutrition

Two key strategic actions that any country can take to promote the greater utilization of NUS to address healthy diets and improved nutrition are:

(i) establish effective research partnerships that undertake nutritional composition work to strengthen a key part of the knowledge base.
(ii) set up multi-sectoral platforms or target already existing platforms that are in a position to use this new knowledge to better mainstream NUS into relevant national nutrition and food security policies, strategies and actions.

Brazil has made good progress in promoting NUS by taking advantage of the multisectoral governance mechanisms already in place under the Fome Zero (Zero Hunger) strategy (Beltrame and Hunter 2015).

Brazilian policies and programmes such as the Food Acquisition Programme (PAA), the National School Meals Programme (PNAE), the Minimum Price Guarantee Policy for Biodiversity Products (PGPM-Bio) and the National Plan for Organic Production and Agroecology (PLANAPO) all provide suitable opportunities and entry points for NUS (Bioversity International 2017). These policy and governance frameworks have been critical in Brazil for the strategic targeting of several of its policies and actions that include promoting diverse NUS in dietary guidelines, supporting production of NUS through public procurement strategies including in schools, as well as prioritizing NUS in relevant national strategies/action plans and agriculture and nutrition policies (Box 1).

Box 1: Brazil's policies to strengthen food and nutrition security through biodiversity

Brazil has a strong foundation for mainstreaming biodiversity, with numerous public policies developing under the influence of the multi-sectoral Zero Hunger (Fome Zero) campaign, begun in 2003. The continued cultivation of NUS is being encouraged by the Food Acquisition Programme (which pays 30% more for organic and agroecological produce grown by family farmers), and the National School Meals Programme (which mandates that 30% of school food comes from family farmers). These policies, along with the National Food and Nutrition Policy, Minimum Price Guarantee Policy for Biodiversity Products, and the National Plan for Agroecology and Organic Production (PLANAPO), all provide entry points for harnessing native biodiversity to improve nutrition and livelihoods.

Two consecutive ordinances for Brazilian sociobiodiversity (no. 163 and 284) now identify 101 native species of nutritional value, and provide incentives for these species to be integrated into public institutional procurement and other initiatives. Ultimately, this will bolster knowledge and dissemination of these NUS and make them profitable for smallholder farmers to conserve, grow, and sell.

Currently in its second phase, PLANAPO has promoted NUS by involving numerous ministries to benefit 60,000 families and 23,000 young farmers through credit schemes, insurance provision and capacity building. PLANAPO's aim is to empower 1 million family farmers to produce healthy agroecological food, while researching the nutritional value of 70 native species and publishing four books documenting the values of regional Brazilian flora.

Finally, the National Council for Food and Nutrition Security, which is an advisory body to the Brazilian presidency, coordinates a wide range of public, private and civil actors to inform food policies and the promotion of healthy diets through provision of incentives to family-based and agroecological production. The most recent National Conference on Food and Nutrition Security, in November 2015, clearly linked biodiversity, and thus NUS, to food quality and recognized the potential of biodiverse foods to solve issues related to food and nutrition security.

Adapted from: Bioversity International 2017.

Policies that incentivize NUS with nutritional value

With increasing calls to better integrate nutrition objectives into food and agriculture including policy incentives for diversification—especially promoting the availability

Table 1 Nutrient-rich plant species recognized by Ordinance No. 284/2018 in Brazil. Source: Ministério do Meio Ambiente (2018)

Scientific name	Common name	Local name
_Acca sellowiana_* (c)	Feijoa	Goiaba serrana
Acmella oleracea (c)	Toothache plant, paracress, Sichuan buttons	Jambu
_Acrocomia aculeata_* (b)	Grugru palm, macaúba palm, and macaw palm	Macaúba
_Anacardium humile_*; _A. nanum_ (w)	Monkey nut; Dwarf cashew	Caju do cerrado
_Anacardium occidentale_* (c)	Cashew tree	Cajú
Ananas comosus (c)	Pineapple	Abacaxi
_Annona crassiflora_* (w)	Marolo or Araticum do cerrado	Araticum, Marolo
Annona mucosa (c)	Biriba or wild sugar-apple	Biribá
Arachis hypogaea (c)	Peanut	Amendoim
_Araucaria angustifolia_* (w)	Paraná pine	Pinhão
_Astrocaryum aculeatum_* (w)	Tucumã, jabarana	Tucumã
Attalea speciosa; _A. tessmannii_ (w)	Babassu palm	Babaçu
_Bactris gasipaes_* (c) (w)	Peach palm	Pupunha
_Bertholletia excelsa_* (w)	Brazil nut	Castanha do Pará/Castanha do brasil
Bixa orellana (c)	Achiote	Urucum
_Butia capitata_* (w)	Jelly Palm	Coquinho azêdo
_Butia catarinensis_*; _B. eriospatha_* (w)	Coastal Jelly Palm; Woolly Jelly Palm	Butiá
_Byrsonima crassifolia_* (b); _B. verbascifolia_* (w)	Savanna serret (murici)	Murici
_Campomanesia adamantium_* (w)	White Guabiroba	Gabiroba
Campomanesia guazumifolia (b)	Sete capotes	Sete capotes
_Campomanesia phaea_* (b)	Cambuci	Cambuci
_Campomanesia xanthocarpa_* (w)	Guabiroba	Guabiroba
_Caryocar brasiliense_*; _C. coriaceum_* (b)	Pequí or souari nut	Pequi
Cereus jamacaru (w)	Mandacaru or cardeiro	Mandacaru
_Dioscorea trifida_* (c) (w)	Cush-cush	Cará amazônico
_Dipteryx alata_* (w)	Baru tree	Baru, Cumbaru
Endopleura uchi (b)	Uxi	Uxi
Eryngium foetidum (c)	Culantro, shadow beni, Mexican coriander, long coriander	Chicória de caboclo
Eugenia brasiliensis (w)	Brazil cherry, grumichama	Grumixama
_Eugenia dysenterica_* (w)	Cagaita	Cagaita
_Eugenia involucrata_* (w)	Cherry of the Rio Grande	Cereja do rio grande
_Eugenia klotzschiana_* (w)	Cerrado pear	Pêra do cerrado
_Eugenia pyriformis_* (b)	Uvaia	Uvaia
_Eugenia stipitata_* (w)	Araza (Araçá, araçá-boi)	Araçá-boi
_Eugenia uniflora_* (c)	Surinam Cherry, Cayenne cherry	Pitanga
_Euterpe edulis_* (c) (w)	Ucara Palm, Heart-of-Palm	Juçara
_Euterpe oleracea_* (c) (w)	Açaí palm	Açaí
_Euterpe precatoria_* (w)	Mountain Cabbage Palm (Açaí solteiro)	Açaí-solteiro
Garcinia brasiliensis; _G. madruno_ (w)	Charichuelo	Bacupari
_Genipa americana_* (w)	Genipapo	Jenipapo
_Hancornia speciosa_* (w)	Mangaba	Mangaba
_Hymenaea courbaril_*; _H. stigonocarpa_* (w)	West Indian Locust, Jatoba	Jatobá
Ilex paraguariensis (c)	Yerba mate	Erva mate
Jacaratia spinosa (w)	Jaracatiá	Jaracatiá, Mamãozinho
Licaria puchury-major (w)	Puxuri, puchuri	Puxuri, puchuri
Manihot esculenta (c)	Cassava	Mandioca
Matisia cordata (w)	South American sapote, Chupa-chupa	Sapota
_Mauritia flexuosa_* (w)	Moriche palm	Buriti
Melothria pendula (c)	Creeping cucumber, guadeloupe cucumber	Mini pepininho

Table 1 (continued)

Scientific name	Common name	Local name
*Myrciaria dubia** (b)	Camu camu	Camu-camu
Myrciaria floribunda (w)	Guavaberry or rumberry	Cambuí
Oenocarpus bacaba; O. distichus** (w)	Bacaba	Bacaba
*Oenocarpus bataua** (w)	Patawa, sehe, hungurahua (Ecuador), mingucha	Patauá
Opuntia elata; O. monacantha* (w)	Prickly pear	Arumbeva
Passiflora alata; P. cincinnata*; P. edulis; P. setacea** (c)	Passion fruit	Maracujá
Paullinia cupana (c)	Guarana	Guaraná
Pereskia aculeata (c)	Barbados gooseberry, blade-apple cactus, leaf cactus, rose cactus, lemonvine	Ora pro nóbis
*Physalis angulata (w); P. pubescens** (c)	Goldenberry	Fisalis
*Platonia insignis** (b)	Bacuri	Bacuri
Plinia cauliflora; P. peruviana** (c)	Brazilian grape	Jabuticaba
Poraqueiba sericea (w)	Umari	Umari
*Portulaca oleracea** (c)	Common purslane	Beldroega
*Pouteria caimito** (c) (w)	Abiu	Abiu
*Psidium acutangulum** (w)	Araçá-pera	Araçá-pera
*Psidium cattleianum** (w)*; P. guineense** (c) (w)	Purple guava; Brazilian guava, sour guava, Guinea guava	Araçá
*Psidium guajava** (c)	Common guava, yellow guava, or lemon guava	Goiaba
Rubus brasiliensis; R. erythroclados; R. rosifolius; R. sellowii (c)	Roseleaf bramble, Mauritius raspberry, thimbleberry, Vanuatu raspberry and bramble of the Cape	Amorapreta
*Schinus terebinthifolius** (c) (w)	Pink pepper	Pimenta-rosa
Sicana odorifera (c) (w)	Cassabanana or casbanan, sikana, and musk cucumber	Croá
Solanum scuticum (w)	Jurubeba	Jurubeba
Solanum sessiliflorum (c) (w)	Cocona	Cubiu
*Spondias mombin** (c) (w)	Yellow mombin	Taperebá, Cajá
*Spondias tuberosa** (c) (w)	Brazil plum (umbu)	Umbu
*Sterculia striata** (w)	Chichá	Chichá
Syagrus coronata (w)	Ouricury palm or licuri palm	Licuri
*Syagrus oleracea** (c)	Gueroba	Gueroba
*Talinum paniculatum** (c)	Ameflower, Jewels-of-Opar	Major gomes
*Theobroma grandiflorum** (c) (w)	Cupuaçu	Cupuaçu
Theobroma cacao (c)	Cacao	Cacau
Tropaeolum pentaphyllum (c) (w)	Lady's Legs (crem)	Crem, Batata crem
*Vasconcellea quercifolia** (w)	Calasacha (Jaracatiá)	Jaracatiá, Mamão do mato
Xanthosoma riedelianum (c)	Mangarito	Mangarito
*Xanthosoma taioba** (c)	Taioba	Taioba

The ordinance lists 101 native food species of nutritional importance, of which 62 are focus species of the BFN project. Next to each species, we indicate whether it is cultivated (c), wild-harvested (w), wild-harvested, but included in a breeding programme (b) or both. BFN species are indicated with an asterisk *

and affordability and increased consumption of fruits and vegetables—a key opportunity has opened up for the better uptake of NUS with nutrition potential. One key example of such an incentivizing policy that specifically targets NUS is Brazil's Ordinance No. 284/2018 ensuring that 101 "Brazilian Sociobiodiversity Native Food Species of Nutritional Value" are now officially defined and formally recognized nationally for the first time (Box 1, Bioversity International 2017). Most of the species in the ordinance are underutilized nutrient-rich fruits that are either cultivated, or sustainably managed and wild-harvested by local communities (Table 1). This represents an important policy lever since it helps set the market price for these crops and wild species, contributes to better understanding and dissemination of knowledge, and could ultimately enhance their promotion and sustainable use through formal recognition, which is important for public food

Fig. 8 School feeding programmes in Brazil and Kenya demonstrate the potential to integrate more NUS. From left to right, Traditional cowpea leaves (*Vigna unguiculata*) preferred over kales in school meals provided at St. Mary's High School, Mundika, Kenya Credit: A. Manjella; Students from Ubatuba school, Brazil, enjoying juçara juice from the edible palm *Euterpe edulis* (Credit: Manejo Comunitário da Juçara e Cambuci (IPEMA); Children in Busia, Kenya, enjoying finger millet porridge (*Eleusine coracana*) for breakfast (Credit: A. Manjella)

procurement including school meals. Similarly, the recently endorsed Biodiversity Conservation Policy for the County of Busia—the first of its kind across Kenya's 47 counties—recognizes the importance of NUS for improved nutrition and food security and has allocated resources to conserve regional food biodiversity, with specific provisions for designated conservation areas and further incorporation of NUS into school meals as well as linking smallholder farmers to institutional markets (Government of the Republic of Kenya 2016).

School meals, public procurement and sustainable and healthy sourcing of NUS

Globally, school meals feed approximately 368 million children daily, representing an annual investment of roughly US$75 billion (WFP 2013). With most countries supporting some form of school feeding, this represents an opportunity to provide and promote healthy foods, and reset eating norms in favor of good nutrition practices. Global recognition is growing about the potential of schools to increase the demand for local farm products, although the actual targeting of NUS has been extremely limited (Bioversity International 2017). As homegrown school feeding programmes are currently being endorsed in many countries—with the aim of procuring food locally and encouraging agricultural development—there are progressively more opportunities to encourage sustainable and healthy sourcing of NUS.

In Kenya, pilot approaches have demonstrated that underutilized, nutrient-rich African leafy vegetables can play a role in linking local farmer groups to school markets at the county and district level, while in Brazil the government has actively pursued the incorporation of NUS into school meals and wider public procurement of food (Fig. 8) (Grisa and Schmitt 2013; Wasike et al. 2016; Beltrame et al. 2016; UNSCN 2017; Tartanac et al. 2018). Indian school feeding programmes have incorporated underutilized minor millets to enhance the nutritional status of schoolchildren in areas of Karnataka state (Bergamini et al. 2013). The 2013 National Food Security Act (Government of India 2013) integrated highly nutritious and climate resilient minor millets in the public distribution systems to benefit millions of school children and the wider population. Although these examples demonstrate that linking NUS to school meals is feasible, most supply chains and implementation frameworks must be further researched and developed to support NUS. This would include establishing adequate levels of incentives/subsidies for growers, procurement rules including minimum price guarantees, adequate infrastructure, and platforms to promote best agronomic and technological practices (Bioversity International 2017).

Dietary guidelines, NUS and healthy eating

National dietary guidelines aligned to local nutrient-rich NUS and food cultures are an example of how to improve the sustainability of food systems while encouraging healthy eating and improved nutrition(Bioversity International 2017). Yet, there are only a few cases in which dietary guidelines have done this effectively. Brazil is often singled out for its progressive dietary guidelines (Fig. 9) that encompass both concepts of sustainability and healthy eating, especially around seasonal and locally grown food biodiversity. Brazil has successfully employed a national platform of experts to work on NUS generating nutritional composition data, documenting traditional recipes, and developing novel NUS-based recipes for modern lifestyles (Beltrame and Hunter 2015). To support the dissemination and use of the revised dietary guidelines, these same experts worked with the Ministry of Health on a new edition of the book *Brazilian Regional Foods*, which was launched in 2015 (Ministério

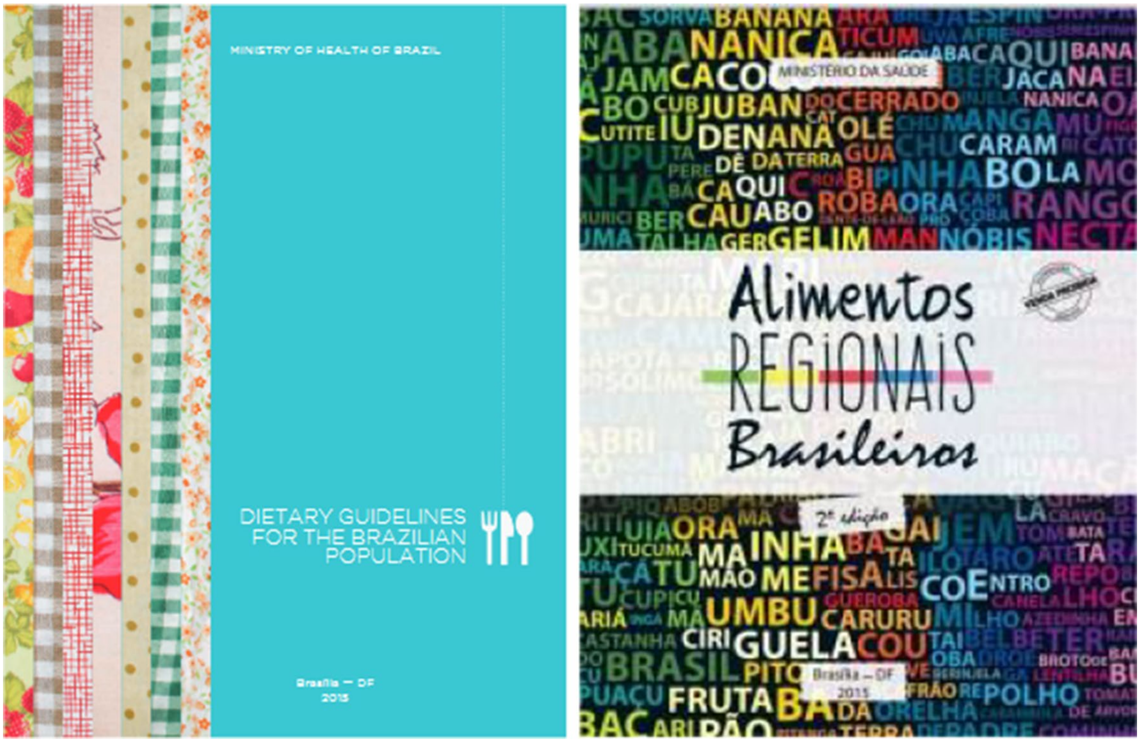

Fig. 9 Brazil's *Dietary Guidelines for the Brazilian Population* and the *Brazilian Regional Foods* developed and published by the Ministry of Health (Ministério da Saúde). The latter includes a chapter on biodiversity for food and nutrition

Fig. 10 Food festivals and fairs in Turkey and Sri Lanka provide opportunities to raise awareness and promote NUS including wild edible plant species Photo credits: Bioversity International/D. Hunter, BFN Project/S. Landersz, UFRGS, M. Rodrigo

da Saúde 2015) (Fig. 9). This included, for the first time, a chapter on "Biodiversity for Food and Nutrition". The book shares recipes and nutritional information of regional foods, including uses of native fruits and non-conventional vegetables. Brazil's focus on regional biocultural heritage, as a key element of the revised national dietary guidelines, represents one method of promoting nutritious NUS that can serve as a model for other countries.

Food and biocultural heritage, tradition and identity: linking NUS to sustainable gastronomy and culinary tourism

Another excellent means of creating consumer awareness of the nutritional benefits of NUS is through food fairs and other events that celebrate biodiversity. A notable example is the Alaçatı Herb Festival in Turkey (Fig. 10), which includes annual collaborations with celebrity chefs and other high profile individuals involved in the food movement (BFN Turkey 2016). The Alaçatı Herb Festival has proven particularly successful, attracting thousands of visitors each year and popularizing wild-harvested herbs. The program includes seminars on local food biodiversity, nutrition and diets, exhibitions, nature walks, the selling of local products and plants, activities for children linked to the festival theme, food and cooking workshops and visits to the Wild Edible Plants Collection Garden in Alaçatı. Another approach in Sri Lanka is "*Hela bojun*: True Sri Lankan taste", market outlets that sell traditional foods and empower rural women who earn a living while conserving and protecting local NUS and making healthy food available at competitive prices. By working at *Hela bojun*, women are able to earn between $ 600–800 a month (Fig. 10). Linked to the *Hela bojun*, cooking demonstrations, gastronomic events and lectures were held on NUS by the Extension and Communication Center of the Department of Agriculture and Wayamba University to demonstrate preparation methods, encourage the preparation of nutritious meals using locally sourced foods, and to encourage the cultivation of diverse varieties in home gardens.

A growing number of chefs and food activists are now popularizing NUS through restaurants and related food activities, initiatives and campaigns (Münke et al. 2015). The potential to mainstream NUS into initiatives such as Chefs for Development, Culinary Breeding Network, the Slow Food Chefs' Alliance and Earth Markets is considerable. Further, the rapid growth of culinary tourism and the financial resources this attracts present unique opportunities for the nutritional value of NUS to be promoted.

International efforts that help mobilize NUS for improving nutrition

Global conventions, treaties, commissions and other initiatives, which oversee and govern the conservation and sustainable use of genetic resources (e.g., Commission on Genetic Resources for Food and Agriculture) are increasingly aware of the nutritional value of NUS and their potential to contribute to food systems transformation and human health. There is also growing awareness of this in the nutrition community, as explained in the paragraph below. Collectively, these developments provide the NUS community (the diverse stakeholders working with these species) with considerable opportunities to promote NUS for healthier diets and more sustainable food systems (IPES-FOOD 2016; FAO 2019; Willett et al. 2019).

The Conference of the Parties (COP) to the Convention on Biological Diversity (CBD)[6] formally recognized the linkages between biodiversity, food and nutrition in 2014, and the need to enhance sustainable use of biodiversity to combat hunger and malnutrition. In 2006, the CBD COP adopted the Framework for a *Cross-Cutting Initiative on Biodiversity for Food and Nutrition,*[7] which provides a useful profile to on-going research and development activities within the CBD that address food, biodiversity and nutrition. Of further support to the integration of biodiversity into national development, accounting and planning processes is the CBD's Strategic Plan for Biodiversity 2010-2020 and the Aichi Biodiversity Targets outlined within (CBD 2010). Countries who are signatories to the CBD are tasked with periodically reviewing and updating their National Biodiversity Strategy and Action Plans (NBSAPs)[8] taking into account national priorities and capacities, but with a view to contributing to the achievement of the global Aichi Biodiversity Targets. Increasing awareness of the link between biodiversity, nutrition and human health within the CBD provides signatory countries the opportunity to use their NBSAP as a national policy instrument to mainstream NUS for the purpose of improving nutrition. Up to now, this national policy instrument has been poorly used by countries for this purpose (Lapeña et al. 2016), however, Brazil provides a useful example of how to approach the NBSAP revision process to ensure the inclusion of nutrition-related objectives, targets and indicators based around the mainstreaming of NUS (Beltrame and Hunter 2015; Hunter et al. 2016).

The FAO Commission on Genetic Resources for Food and Agriculture (CGRFA),[9] at its 14th session in 2013, formally recognized nutrients and diets, as well as food, as ecosystems services to increase awareness of human nutrition as a concern for the environment and agriculture sectors. The Commission at that session requested the preparation of guidelines for mainstreaming biodiversity into all aspects of nutrition, including nutrition education, nutrition

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[6] Convention on Biological Diversity https://www.cbd.int/.

[7] Cross-cutting initiative on biodiversity for food and nutrition https://www.cbd.int/decision/cop/?id=11037.

[8] National Biodiversity Strategies and Action Plans https://www.cbd.int/nbsap/.

[9] Commission on Genetic Resources for Food and Agriculture http://www.fao.org/nr/cgrfa/cgrfa-home/en/.

interventions, nutrition policies and programmes. At its 15th session in 2015, the CGRFA formally adopted the *Voluntary Guidelines for Mainstreaming Biodiversity into Policies, Programmes and National and Regional Plans of Action on Nutrition*[10] (FAO 2016), providing guidance to countriesfor the integration of NUS into relevant policies and actions to help address malnutrition. Most recently, the report on *The State of the World's Biodiversity for Food and Agriculture* acknowledges the need for more evidence on NUS including "nutrient-rich orphan and new crops" as well as multiple sections devoted to wild edibles (FAO 2019).

The importance of NUS is also gaining recognition by the nutrition and health community. The Second International Conference on Nutrition (ICN2), jointly convened by FAO and the World Health Organization in 2014, focused on policies aimed at eradicating malnutrition in all its forms and transforming food systems to make nutritious diets available to all. Participants at ICN2 endorsed the *Rome Declaration on Nutrition*[11] and the *Framework for Action,*[12] which include recommendations to support the better utilization of NUS, especially recommendation 10 to "promote the diversification of crops including underutilized traditional crops, more production of fruits and vegetables, and appropriate production of animal source products as needed, applying sustainable food production and natural resource management practices" and recommendation 42 to "improve intake of micronutrients through consumption of nutrient-dense foods, especially foods rich in iron and promote healthy and diversified diets".

Finally, the 2030 Sustainable Development agenda features UN Sustainable Development Goal 2—SDG2—(UN 2015), *End hunger, achieve food security and improve nutrition and promote sustainable agriculture,* where nutrition, NUS, and genetic diversity coalesce. SDG Target 2.5 states:

> *By 2020, maintain the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at the national, regional and international levels, and promote access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed.*

The Crop Trust,[13] with its mission to ensure the conservation and availability of crop diversity for food security worldwide, has recently initiated the Food Forever campaign to highlight the importance of food diversity and contribute to implementing SDG Target 2.5. This also provides the NUS community with an opportunity to contribute to two of the key challenges for sustainable development—shrinking diversity and malnutrition—and the synergies of bringing both together.

Conclusion

The multi-stakeholder approach described and used in the four countries highlighted the viability of integrating neglected and underutilized species (NUS), including orphan crops and wild edible plant species, into production and consumption systems. Sustainable food systems—defined as food systems "that deliver food and nutrition security for all in such a way that the economic, social and environmental bases to generate food security and nutrition for future generations are not compromised" (HLPE 2014)—are essential not only for achieving SDG 2, but can contribute multiple environmental outcomes linked to the SDGs and the Aichi Biodiversity targets as well as social and economic benefits (IPES-FOOD 2016; FAO 2019; Willett et al. 2019). These include: curbing biodiversity loss; mitigating climate change; strengthening seed systems to ensure that biodiversity is conserved, available and accessible by those who need it most—particularly women and men smallholder farmers who play a key role in conserving this diversity on-farm and in the wild; developing markets and agri-businesses that ensure diverse foods are available and affordable by low-income consumers; revitalizing local knowledge and cultural heritage; as well as supporting rural development and strengthening local economies (Hunter et al. 2017a).

This paper has highlighted the need for greater links between evidence and policy as well as more coherent and coordinated action at local, national, and global levels by the NUS community. To maximize the nutritional potential of NUS, this community—the researchers, universities, government agencies, national ministries, local governments, municipalities, small-scale producers and civil society working with NUS (Hunter et al. 2016)—must coordinate to achieve synergies and avoid duplication of efforts. At present, it could be argued that the NUS community is very much disconnected resulting in piecemeal evidence and ad hoc actions, which minimize the impact/potential of NUS to reorient food systems towards greater diversity. The NUS community must lobby and advocate its case to both the agriculture and nutrition/health sectors demanding greater research investments into the analyses of food biodiversity, metrics to measure impact and the establishment of locally

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[10] http://www.fao.org/3/a-i5248e.pdf.

[11] http://www.fao.org/3/a-ml542e.pdf.

[12] http://www.fao.org/3/a-mm215e.pdf.

[13] https://www.croptrust.org/.

relevant knowledge platforms. Opportunities exist to do this especially around SDG 2 and specifically Target 2.5.[14]

The NUS community must think more creatively to improve utilization of these genetic resources, and not just by developing niche markets for NUS, which have been highly developed for the likes of rocket and quinoa, but by exploring new narratives through, for example, the diversification of school feeding and public procurement programs that link to smallholder farmers—as trialed in Brazil and Kenya—or by stimulating demand for diverse and healthy foods by engaging with gastronomy movements and celebrity chefs.

Based on the experience of BFN countries, recommendations for decision makers who wish to engender food systems transformation using NUS to simultaneously address environmental, social and economic concerns are the following:

- Support research aimed at analyzing the nutritional value of NUS, as well as domestication efforts to make wild edibles or partly domesticated orphan crops available and affordable for all consumers.
- Promote the use of NUS through dietary guidelines to diversify food and agricultural production systems at local and national levels.
- Develop policy incentives for NUS that support diversification of agriculture and food systems.
- Invest in short supply chains for new and healthy biodiversity products, and support agri-businesses around local biodiversity to improve farmers' livelihoods and strengthen local economies.
- Use public food procurement that supports the sourcing of local, sustainable and healthy food and stimulates the production and consumption of NUS.
- Incorporate the use of culturally appropriate NUS into existing national school meal programs and nutrition education activities including school gardens.
- Develop awareness raising campaigns focusing on the importance of NUS for diet diversification, nutrition and economic development.

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[14] Target 2.5: By 2020, maintain genetic diversity of seeds, cultivated plants, farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at national, regional and international levels, and ensure access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge as internationally agreed.

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