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SUPPLEMENT ARTICLE

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Future Smart Food: Harnessing the potential of neglected and underutilized species for Zero Hunger

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Abstract

Achieving Sustainable Development Goal 2: 'Zero Hunger'—eradicating all forms of hunger and malnutrition—is a major challenge in many developing countries. To be successful, agriculture and food policies need to target both production and consumption. Conventional agri-food systems in developing countries could become more sustainable through agricultural diversification. In Asia, over-reliance on a few staple crops is a leading cause of low dietary diversity and persistent malnutrition. Promising neglected and underutilized species (NUS) that are nutrient dense, climate resilient, economically viable, and locally available or adaptable have been prioritized as Future Smart Food (FSF) and have a central role to play in the fight against hunger and malnutrition. An enabling environment for agriculture diversification with a food system approach—to promote sustainable production, processing and consumption of FSF—is essential for achieving Zero Hunger. This article (a) provides the context of hunger and malnutrition and highlights the features and gaps in current agriculture and food systems, (b) demonstrates the multidimensional benefits of FSF as an effective means to bridge production and nutrition gaps to address Zero Hunger and (c) offers a holistic food systems approach that promotes sustainable production, processing and consumption of FSF as a key element for achieving Zero Hunger.

KEYWORDS
food consumption, food policy, food security, micronutrient malnutrition, nutrition, policymaking

1 | INTRODUCTION

1.1 | Hunger and malnutrition

Ending hunger and all forms of malnutrition are part of the second Sustainable Development Goal (SDG2): Zero Hunger. Food security in the Asia-Pacific region has improved over the last decade. In line with the Millennium Development Goals, the region halved the proportion of undernourished people between 2000 and 2015; however, there are still around 490 million undernourished people (62% of the world's total), of which 281 million are in South Asia (Food and Agriculture Organization of the United Nations [FAO], International Fund for Agricultural Development [IFAD],& World Food Programme [WFP], 2015).

The Asia-Pacific region continues to face a high prevalence of malnutrition, often leading to stunting. It is estimated that 93 million children under the age of 5 (~30%) are stunted, of which 68 million

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are in South Asia. The highest levels of stunting in children under 5 in the Asia-Pacific region are in Lao PDR (43.8%), India (38.7%), Nepal (37.4%), Bangladesh (36.1%), Myanmar (35.1%), Bhutan (33.6%) and Cambodia (32.4%)[1] (Figure 1).

High rates of micronutrient deficiency also prevail in many countries in Southeast Asia and South Asia. For instance, in most Association of Southeast Asian Nations (ASEAN) countries, the occurrence of anaemia (caused, among others, by iron deficiency) is alarming, amounting to more than 40% for children under the age of 5(ASEAN, United Nations Children's Fund [UNICEF],& World Health Organization [WHO], 2016). Countries suffering from severe micronutrient deficiencies (HHI > 25) include Nepal, India, Bangladesh, Bhutan and Lao PDR.[2] Compounding this problem is the parallel increase in overweight and obesity, especially in urban areas. In the Asia-Pacific region, 15% of adults are overweight because of changing dietary patterns, and childhood obesity is increasing (FAO, 2016b).

A comparative analysis of malnutrition prevalence in Cambodia, Lao PDR, Myanmar and Nepal shows that Lao PDR has the highest rate of undernourishment, with 18.5% of the population undernourished, followed by Cambodia and Myanmar (14.2% each) and Nepal with 7.8% (Figure 2).

Stunting, wasting and underweight are important indicators of malnutrition. A common feature is a high prevalence of stunting, exceeding 30% in all four countries. In terms of underweight and wasting, Nepal is the highest at 37.4% and 11.3%, respectively.

Myanmar has the highest rates of anaemia among children (57.4%), pregnant women (54%) and women of reproductive age (46.6%), followed by Cambodia, Lao and Nepal with rates ranging from 35% to 55%.

Key messages

- Agricultural diversification is key to make agri-food systems more sustainable.
- In Asia, over-reliance on a few staple crops is a leading cause of low dietary diversity and persistent malnutrition.
- Promising neglected and underutilized species (NUS) that are nutrient dense, climate resilient, economically viable, and locally available or adaptable have been prioritized as Future Smart Food (FSF) and have a central role to play in the fight against hunger and malnutrition.
- An enabling environment for agriculture diversification with a food system approach—to promote sustainable production, processing and consumption of FSF—is essential for achieving Zero Hunger.

1.2 | Current agriculture and food systems

1.2.1 | Main problems

There are two main problems in the current agriculture and food systems: (a) concentration on a few staple crops leading to unbalanced diets and ultimately malnutrition and (b) conventional (mainstream) agricultural production following a high input–high output model that makes farming more vulnerable to environmental shocks. Conventional agriculture favours monocultures, which cause ecological imbalance and loss of biodiversity. An estimated 75% of crop genetic diversity has been lost since the 1900s (FAO, 2017). The dependence on a few staple crops poses a threat to food security, especially against a climate change background: Variations in temperature and rainfall patterns will disrupt conventional agriculture systems that require relatively uniform conditions. However, traditional farming systems, which are often relegated to remote and marginal areas, will be affected. Thus, the livelihoods and food security of vulnerable groups, such as smallholder farmers, children, women and indigenous people that depend on traditional crops, will be at risk (FAO, 2018).

[1]2010 figures taken from FAO's (2016b) Regional Overview of Food Insecurity: Asia and the Pacific.

[2]2011 figures. Hidden Hunger Index (HHI) taken from FAO's (2016b) Regional Overview of Food Insecurity: Asia and the Pacific.

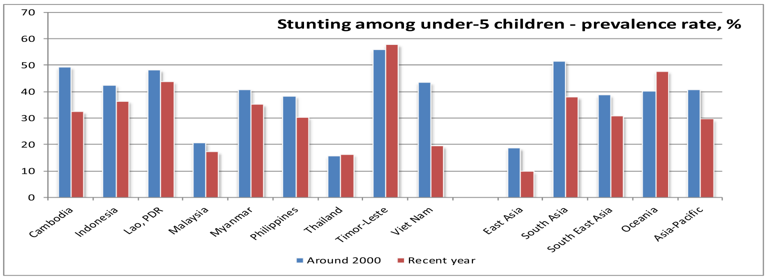
1.2.2 | Implications

Looking at world food security from a consumer perspective, there will be numerous challenges over the next decades. The world population is expected to increase to 9.7 billion by 2050 (United Nations [UN], 2015). By 2050, urban areas are projected to be home for 66% of the world population (UN, 2014). Rising incomes will lead to changing dietary patterns: Consumers will reduce their intake of traditional staples, such as rice, and spend more on other cereals, pulses, fruits and vegetables, among others (FAO, 2018). The increased demand for food, further exacerbated by changing consumption and dietary patterns, due to increasing urbanization and rising middle-class incomes, will exert pressure on the agriculture sector to increase productivity. At the same time, rural populations in marginal and exposed areas will face more significant problems to feed themselves because of climate change and environmental degradation.

The combined effects of climate change, declining agricultural biodiversity, land and water scarcity, and environmental degradation are significant challenges for world food security. There is already a notable slowdown in yield growth in staple crops, particularly rice and wheat. From 1989 to 2008, global yield increase rates averaged only 1.6% for maize, 1.0% for rice and 0.9% for wheat, which are insufficient to meet future food demands without resorting to agricultural land expansion. However, Asia has little arable land available for expansion. For instance, ASEAN's arable land makes up just 15.6% of

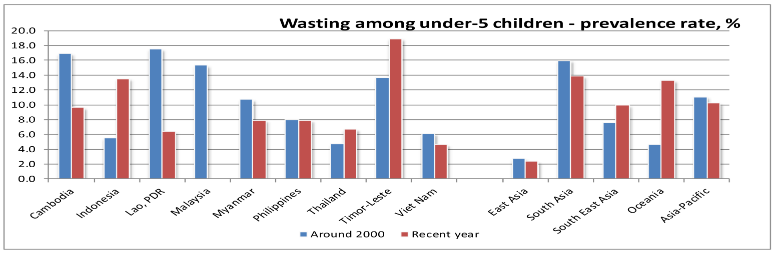
Stunting prevalence among under-5 children, %

	Around 2000	Recent year	Reduction rate % p.a.
Cambodia	49	32	3.0
Indonesia	42	36	1.2
Lao, PDR	48	44	0.9
Malaysia	21	17	2.7
Myanmar	41	35	1.7
Philippines	38	30	1.6
Thailand	16	16	-0.6
Timor-Leste	56	58	-0.5
Viet Nam	43	19	6.4
East Asia	19	10	
South Asia	52	38	
South East A	39	31	
Oceania	40	48	
Asia-Pacific	41	30	



Wasting prevalence among under-5 children, %

	Around 2000	Recent year	Reduction rate % p.a.
Cambodia	16.9	9.6	4.1
Indonesia	**5.5**	13.5	-6.7
Lao, PDR	17.5	6.4	9.6
Malaysia	15.3		
Myanmar	10.7	7.9	3.4
Philippines	8.0	7.9	0.1
Thailand	4.7	6.7	-5.7
Timor-Leste	13.7	18.9	-4.5
Viet Nam	6.1	4.6	2.2
East Asia	2.7	2.3	
South Asia	16.0	13.9	
South East A	7.5	9.9	
Oceania	4.6	13.3	
Asia-Pacific	11.0	10.2	



Underweight prevalence among under-5 children, %

	Around 2000	Recent year	Reduction rate % p.a.
Cambodia	39.5	23.9	3.7
Indonesia	24.8	19.9	1.7
Lao, PDR	36.4	26.5	2.9
Malaysia	16.7	12.9	3.8
Myanmar	30.1	22.6	3.2
Philippines	28.3	19.9	2.4
Thailand	7.0	9.2	-4.5
Timor-Leste	40.6	45.3	-1.6
Viet Nam	26.7	12.1	6.3
East Asia	7.8	3.6	
South Asia	43.5	28.8	
SEA	25.1	18.3	
Pacific	16.8	26.2	
All 25 total	31.0	20.6	

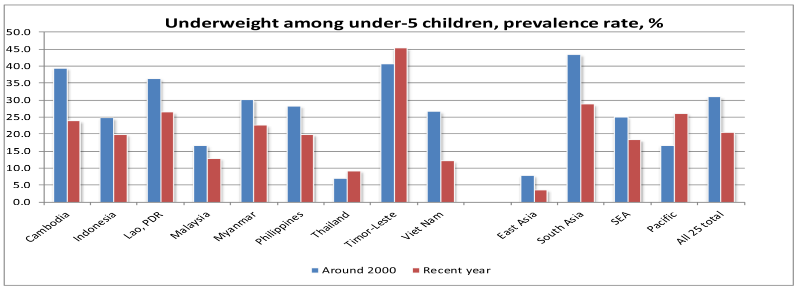


FIGURE 1 Stunting, wasting and underweight in Southeast Asian countries in 2015

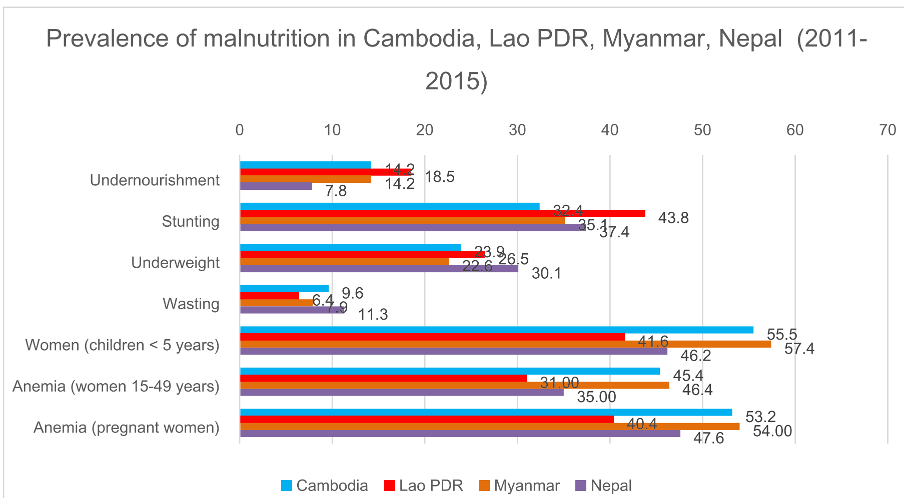


FIGURE 2 Prevalence of malnutrition in Cambodia, Lao PDR, Myanmar, Nepal (2011–2015). Source: FAO (2019) and UNICEF–WHO–World Bank joint database

Source: FAO 2015, World Bank 2015, WHO 2015, UNICEF-WHO-World Bank joint database

its total land area, and little space is available for expansion (Desker, Caballero-Anthony, & Teng, 2013). Without the expansion of agricultural areas, farmers in ASEAN countries need annual yield increases of more than 1.7% to feed the growing population. In addition, some studies predict that climate change will result in a 14% decline in rice production in South Asia, compared with a no-climate-change scenario, and a global decline of 44–49% in wheat production and 9–19% in maize production (Nelson et al., 2009). Bridging the food security gaps remains a significant challenge, which will require a fundamental transformation of current food and agricultural systems (FAO, 2018).

1.2.3 | Production and nutrition gaps

There are two major gaps in our current food and agricultural systems: (a) production gap—to feed 9.7 billion people by 2050, global food production will need to increase by 50% (FAO, 2017). As yields in major irrigated wheat, rice and maize systems appear to be near 80% of the yield potential, it is unlikely that the production of conventional commercial staple crops will meet the increasing demand. (b) Nutrition gap—conventional staple foods do not supply all the ingredients for a balanced diet, leading to the current status of malnutrition and making it difficult to ensure sufficient nutrients for an additional 2 billion population in 2050. In sum, a paradigm shift in food systems towards sustainable production and the consumption of diversified food is required to address the global food challenges (FAO, 2018).

2 | KEY MESSAGES: FUTURE SMART FOOD AS A MEANS TO BRIDGE PRODUCTION AND NUTRITION GAPS TO ADDRESS ZERO HUNGER

Future Smart Foods (FSFs) are defined as neglected and underutilized species (NUS) that are nutrient dense, climate resilient, economically viable, and locally available or adaptable (FAO, 2018). NUS are key elements of the agrobiodiversity needed for sustainable agriculture. Globally, of the 300,000 to 500,000 plant species, 30,000 have been identified as edible plant species; of these, more than 7,000 crop species have been cultivated, domesticated or collected from the wild as a food throughout the history of humanity (Garn & Leonard, 1989). However, no more than 150 crop species are cultivated commercially, with 103 of these providing up to 90% of the calories in the human diet. Three main crops, namely, rice, maize and wheat, provide 60% of the world's food energy intake (FAO, 1995). This means that many edible plant species remain relatively ‘underutilized’, yet they could play a significant role in reducing mainstream agriculture's over-reliance on a few staple crops (FAO, 2018).

Generally speaking, NUS are good sources of essential foodstuffs—micronutrients, protein, energy and fibre—which would contribute to food and nutrition security. As well as having superior nutritional qualities, many NUS can be grown on marginal soils and easily fit into (smallholder) integrated crop production systems. Many NUS also have the unique ability to tolerate various environmental stresses, which can make production systems not only more diverse but also more sustainable and climate resilient (FAO, 2018).

However, not all NUS are nutrient dense or resilient to climate change. FAO classifies NUS as FSF if they meet the following four criteria (FAO, 2018):

1. nutrient dense (enhance nutrition),
2. climate resilient (e.g. require low inputs, promote climate change resiliency and environmentally friendly by reducing soil runoff and erosion),
3. economically viable (e.g. generate income and reduce drudgery) and
4. locally available or adaptable.

3 | METHODOLOGY

FAO, in collaboration with national and international partners, launched an FSF Initiative in 2016 to support countries in the identification of NUS with high potential to improve existing agricultural and food systems. The FSF Initiative started with an interdisciplinary priority-setting exercise composed of three phases in eight Asian countries (Appendix A):

1. Stage 1: scoping and identification of NUS (prior to Regional Expert Consultation)
   - Preliminary scoping report on the availability of NUS at the national level
   - Circulation of a preliminary scoping report
   - Review of preliminary scoping report by international experts designated independently by partner institutions
2. Stage 2: validation and prioritization of NUS (during Regional Expert Consultation)
   - Joint validation of preliminary scoping reports from the selected countries
   - Ranking of high-potential NUS according to the four prioritization criteria (i.e. nutrient dense, climate resilient, economically viable, and locally available or adaptable)
   - Prioritization of 5–6 NUS crops per country
3. Stage 3: mapping
   - Mapping of selected NUS according to their geographical availability/prominence using geographic information system (GIS)
   - Preparation of GIS reports on selected crops by country

The preparation of national scoping reports on promising NUS was a key step in the priority-setting exercise. In consultation with partners, FAO developed methodology and guidelines for the national experts to conduct preliminary scoping studies on NUS (Appendix B), with emphasis on the four FSF criteria. Target food crops were selected from the following groups: (a) cereals, (b) roots and tubers, (c) nuts and pulses, (d) horticulture and (e) others. Only NUS present in the national gene banks were considered for the exercise. The four FSF prioritization criteria were adapted as (a) nutritional benefits, (b) agricultural sustainability, (c) ecological sustainability and (d) socio-economic sustainability, with each criterion further broken down into a series of parameters (e.g. water requirement, drought tolerance and area under cultivation), requiring experts to provide an aggregated dataset on NUS related to each criterion (Appendix A):

(a) Nutrition	➢ Nutritional value and health benefits
(b) Agricultural production practices	➢ Local knowledge, availability and seasonality ➢ Productivity, intercropping and competing with other crops
(c) Ecological sustainability	➢ Processing ➢ Agroecology ➢ Adaptation to local climate and soil types
(d) Socio-economic sustainability	➢ Cultural acceptance and consumer preferences ➢ Access to markets and potential income generation

The national scoping reports on promising NUS were prepared by national experts nominated by the Ministry of Agriculture or national agriculture research institution of participating countries based on the expertise required as per guideline for preparation of national report from FAO. In some countries, a taskforce was established by the Ministry of Agriculture or designated national agriculture research institute to conduct the exercise jointly; for instance, in Nepal, a team of eight national experts from Nepal Agricultural Research Council and Ministry of Agricultural development in Nepal was established to undertake the exercise. In other countries, the lead national expert was identified by the Ministry of Agriculture who was responsible to coordinate with other relevant experts in the country; for instance, in Myanmar, national expert from Department of Agricultural Research of Ministry of Agriculture, Livestock and Irrigation in Myanmar took the lead in conducting the exercise. National experts first listed potential target NUS by food groups, that is, cereals, roots and tubers, nuts and pulses, horticulture and others (e.g. fruit trees). They then assessed the listed NUS based on existing information, before ranking them within each food group. Up to six priority crops per food group were selected in the national prioritization exercise, on the basis of the given parameters within each priority criterion.

The preliminary country scoping reports were circulated by the FAO and reviewed by 22 international experts designated by the international institutes. The international experts, representing various disciplines (nutrition, agriculture, ecology and socio-economics), had knowledge of NUS and relevant experience in South Asia or Southeast Asia. Each national expert was assigned international experts from preidentified disciplines, coordinated by the FAO. National experts revised the preliminary results prior to the Regional Expert Consultation.

The Regional Expert Consultation served as a second-round collective review and validation process: On the basis of the first-round review, the country experts revised their national reports and presented their preliminary results of the prioritized national NUS, in terms of nutrition, agriculture, ecology and economic features for cross-disciplinary review and validation. Prof. Kadambot Siddique (FAO Special Ambassador for International Year of Pulses 2016) and Dr Mahmoud El Solh (Vice Chair of High Level of Panel of Experts of Committee on World Food Security of FAO, WFP and IFAD and Former Director General, International Center for Agricultural Research in the Dry Areas [ICARDA]) co-chaired the review. As more scientific data were available on the nutrient, agriculture and ecology-related features of the NUS, these parameters were given more weight than socio-economic parameters in the prioritization process. Because nutrition density and climate resilience are crucial for addressing Zero Hunger, only crops meeting both criteria could be selected for FSF. On the basis of the validation exercise, each country prioritized 5–6 NUS as FSF. For instance, Figure 3 presents the selected FSF in Bangladesh and Figure 4 presents the selected FSF in Myanmar.

Applying the same methodology, the NUS scoping and prioritization exercise were entirely country driven, and the resulting NUS priority lists were determined by a multidisciplinary review of scientific data and specific conditions of the participating country. For example, a crop considered a NUS in one country might not be a NUS in another country.

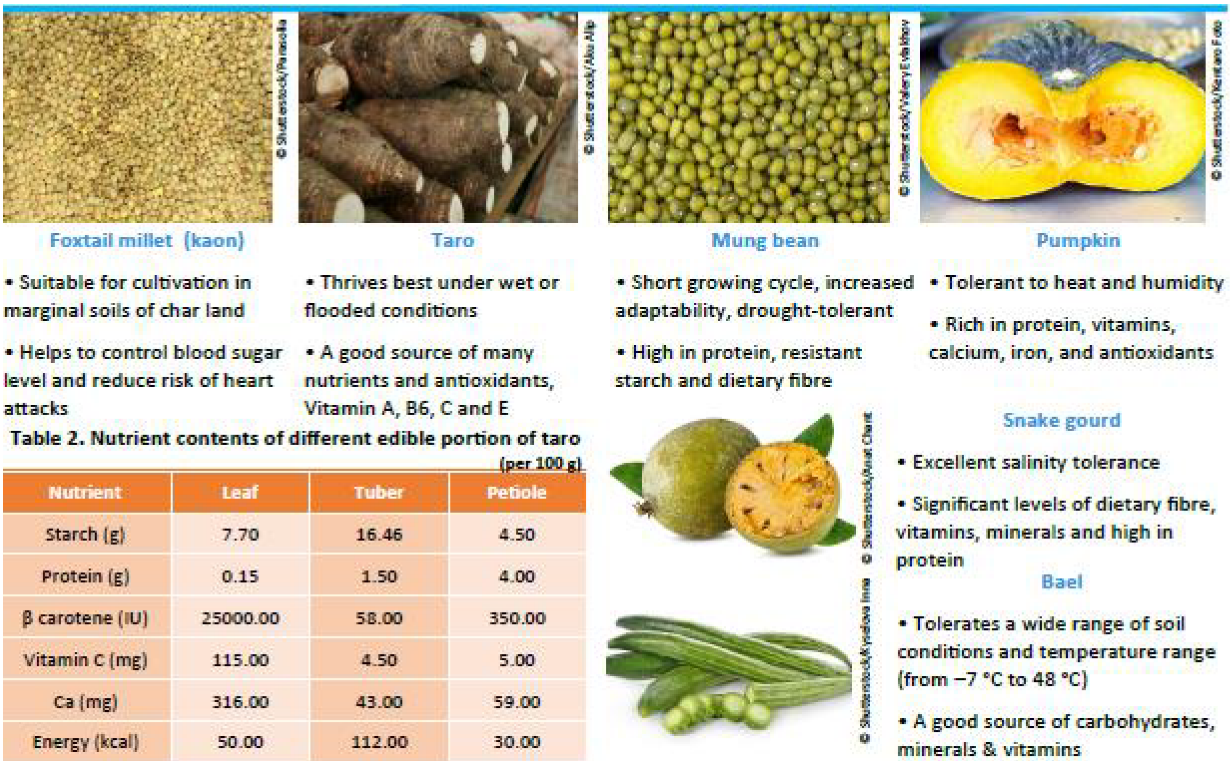
At the end of the exercise, 39 FSFs were selected and prioritized by the eight participating countries: Bhutan, Bangladesh, Cambodia, India (West Bengal), Lao PDR, Myanmar, Nepal and Vietnam (Figure 5) All chosen FSFs have the potential to transform current conventional agricultural practices into more sustainable, nutrition-sensitive and climate-resilient agriculture systems (FAO, 2018).

4 | RESULTS: MULTIDIMENSIONAL BENEFITS OF FSF

4.1 | Nutritional and health benefits

In Asia, where rice is a major staple, the nutritional qualities of many FSFs can substantially improve protein and micronutrient contents in rice-based diets, thus addressing non-communicable diseases that afflict millions of people (FAO, 2018).

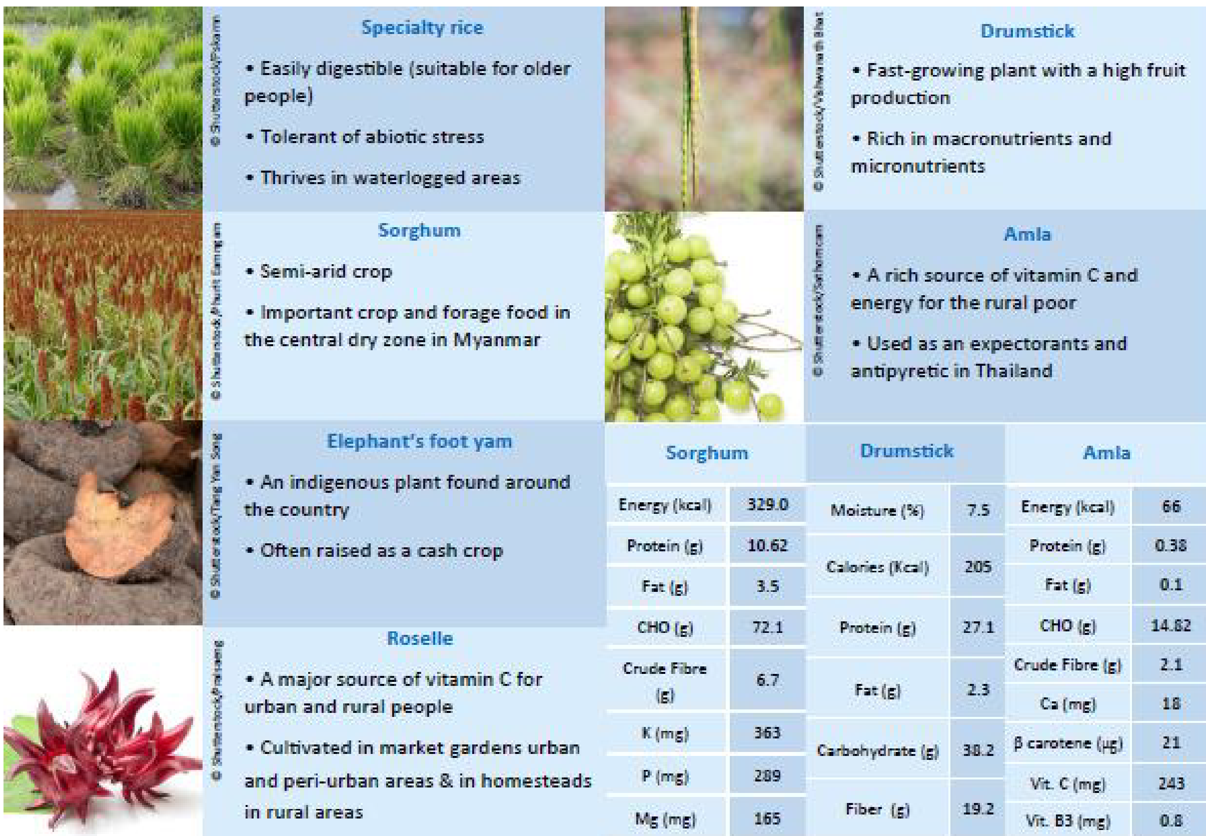
Pulses are an outstanding example, being prioritized as FSFs by Cambodia, India, Nepal, Myanmar and Vietnam. Pulses contain many ingredients that are important for a healthy diet—their proteins, nutrients and dietary fibres can help to reduce the risk of developing chronic non-communicable diseases. For example, chickpea, in comparison with polished white rice, contains three times more protein, four times more dietary fibre, four times more iron and 70 times more folate, though the energy level is similar in both crops. Similarly, lupin contains five times more protein, eight times more dietary fibre, four times more iron and 44 times more folate than rice. (Pulses in the FAO definition include dry beans, field pea, chickpea, cowpea, lupin, common bean, faba beans, lentil, mung bean, pigeon pea, urd bean and others; grain legumes used for oil extraction, such as soybean and peanut, are excluded; FAO, 2016a.)



Nutrient	Leaf	Tuber	Petiole
Starch (g)	7.70	16.46	4.50
Protein (g)	0.15	1.50	4.00
β carotene (IU)	25000.00	58.00	350.00
Vitamin C (mg)	115.00	4.50	5.00
Ca (mg)	316.00	43.00	59.00
Energy (kcal)	50.00	112.00	30.00

Source: FAO, 2019

FIGURE 3 The selected Future Smart Foods in Bangladesh. Source: FAO (2019)



Sorghum	
Energy (kcal)	329.0
Protein (g)	10.62
Fat (g)	3.5
CHO (g)	72.1
Crude Fibre (g)	6.7
K (mg)	363
P (mg)	289
Mg (mg)	165

Drumstick	
Moisture (%)	7.5
Calories (Kcal)	205
Protein (g)	27.1
Fat (g)	2.3
Carbohydrate (g)	38.2
Fiber (g)	19.2

Amla	
Energy (kcal)	66
Protein (g)	0.38
Fat (g)	0.1
CHO (g)	14.82
Crude Fibre (g)	2.1
Ca (mg)	18
β carotene (µg)	21
Vit. C (mg)	243
Vit. B3 (mg)	0.8

Source: FAO, 2019

FIGURE 4 The selected Future Smart Foods in Myanmar. Source: FAO (2019)

Cereals	Roots & Tubers	Pulses	Fruits & Vegetables	Nuts, Seeds & Spices
Buckwheat	Taro	Grass pea	Drumstick	Linseed
Tartary buckwheat	Swamp taro	Faba bean	Chayote	Walnut
Foxtail millet	Purple yam	Cow pea	Fenugreek	Nepali butter tree
Proso millet	Fancy yam	Mung bean	Snake gourd	Perilla
Finger millet	Elephant's foot yam	Black gram	Pumpkin	Nepali pepper
Sorghum	Sweet potato	Rice bean	Roselle	
Amaranth		Lentil	Indian gooseberry	
Grain amaranth		Horse gram	Jack fruit	
Quinoa		Soybean	Wood apple	
Specialty rice				

Source: FAO, 2018

FIGURE 5 Selected Future Smart Foods in eight countries in Asia. Source: FAO (2018)

Anaemia is widespread in many Asian countries: Higher consumption of pulses could lower the incidence. For example, lentils are rich in micronutrients, especially iron (Fe), zinc (Zn) and selenium (Se), and have the potential to provide the amounts necessary for an adequate diet (Migliozzi, Thavarajah, Thavarajah, & Smith, 2015). An empirical study reported the impact of an Fe-rich lentil diet on Fe-deficient anaemic children in Sri Lanka: The pilot study with 33 mild anaemic children (haemoglobin levels = 11 ± 0.8 g/dl) showed that the group fed with 50 g of red lentils per day for 2 months had significantly improved their Fe status (Migliozzi et al., 2015) (Table 1). These preliminary results show that even the short-term introduction of lentils into children's meals can help to reduce anaemia among children.

Millets (*Panicum*) are another example of promising FSF. Millets played a key role in household food security and dietary diversity in many Asian countries before rice began to replace millet as the staple grain. Millets have protein content close to that of wheat, and many millets are rich in B vitamins (especially niacin, B_6 and folacin), calcium, iron, potassium, magnesium and zinc. Despite being cultivated for centuries, minor millets account for less than 1% of the food grains produced in the world (Chang et al., 2012). The restricted consumption and limited commercial application of millets go hand in hand with the relative neglect of millets in research.

TABLE 1 Per cent improvement in mildly anaemic children (n = 33) in Sri Lanka after a 60-day red lentil feeding trial

Indicator	0 days	60 days	% improvement
Haemoglobin (g/dl)	11.1	11.8	6.3
Serum Fe (μg/dl)	51.5	89.8	74.4
Total Fe binding capacity (μg/dl)	405.3	377.6	−6.8
Transferritin saturation (%)	12.8	24.3	89.8
Serum ferritin (ng/ml)	29.5	41.2	39.7

A study conducted in Karnataka State, India, reported improved nutritional status by integrating minor millets into school feeding programmes (Chang et al., 2012). The study measured the impact of replacing rice with finger or foxtail millet by assessing the progress of height/weight measures and haemoglobin levels in 60 school children (11–14 years old). The children had suffered from chronic energy deficiency. However, a 3-month intervention incorporating millet into their diets increased haemoglobin levels by 32.0–37.6%. Millets thus have the potential to improve the nutritional status of school-age children (Fanzo & Hunter, 2013).

The moringa tree (*Moringa oleifeira*) is another example of FSF with superior nutritional and health benefits: The leaves and seed pods are excellent sources of protein, fresh leaves are an outstanding source of vitamin C and dried leaf powder offers a more concentrated version of the same nutrients and vitamins. Plant leaves and seed pods also have high concentrations of calcium, iron, potassium, magnesium and B vitamins. An empirical study confirmed that daily use of the leaves and seeds of the moringa tree provides the recommended dietary allowance for vitamins C and A, and minerals, such as calcium and potassium (Asghari, Palizban, & Bakhshaei, 2015; FAO, 2018).

4.2 | Climate resilience

FSFs could be the solution for many agricultural issues we face today, especially those related to climate uncertainty. They are well adapted to stress conditions of extreme environments and form part of subsistence farming, which are often marginal and harsh, thus offering sustainable food production. FSFs can be grown successfully in marginal and degraded wastelands, with few inputs. They contribute 'to increased agricultural production, enhanced crop diversification, increased income opportunities, and improved environment' (Adhikari et al., 2018).

Pulses are environmentally friendly for cropping systems: They contribute to cropping system diversity when grown with crops of other plant families (e.g. cereals), disrupting pest and disease cycles that develop during monocropping. Unlike cereal and oilseed crops, pulses can symbiotically fix nitrogen, leading to significant advantages for agricultural sustainability, in both developing and developed countries (Foyer et al., 2016). Pulses contribute to soil fertility, primarily through biological nitrogen fixation and also by adding organic matter and releasing soil phosphorus. As a good source of protein, pulses could lead a land use shift away from livestock—a move that would substantially lower the carbon footprint for protein production destined for human consumption. Side products, such as stems and greens not suitable for human diets, can be used as a feed source and add value to the sustainability and productivity of cropping systems (FAO, 2018).

Cowpea (*Vigna unguiculata*) is an FSF prioritized by Vietnam and Cambodia, among others. It is not only a protein-rich legume, but it also provides fodder for livestock, soil improvement benefits through nitrogen fixation and household benefits in the form of cash and income diversity. It thrives in arid and semi-arid tropics covering Asia, Africa, Europe, the United States and Central and South America (Consultative Group for International Agricultural Research [CGIAR], 2019).

Millets, with strong drought tolerance, have been prioritized as FSF by most South Asian countries, including Bangladesh, Bhutan and India. Millets perform well in this regard, as they are resilient to a variety of agro-climatic adversities, such as poor soil fertility and limited rainfall. They play an important role in supporting marginal agriculture, for example, in the hilly and semi-arid regions of India (Ravi et al., 2010). Millets are annual C_4 plants (which photosynthesize following the C_4 photosynthesis mechanism) that can grow on a wide variety of soils ranging from clay loams to deep sands, but the best soil for cultivation is deep, well-drained soil. This makes them suitable for cultivation by smallholder farmers in semi-arid areas where deep sands and sandy loam soils dominate (FAO, 2018).

Taro (*Colocasia esculenta* (L.) Schott) is an FSF prioritized by Nepal, Bangladesh, Cambodia and Vietnam, among others. It is a rich source of carbohydrates, vitamins A and C, and protein. Leaves and corms of taro are edible and also serve as a leafy vegetable supplying mineral nutrients to the traditional diets of smallholder farmers. Taro tolerates waterlogging (Modi, 2004) and could be an ideal crop for dry areas that are predicted to experience incidences of flash floods with reported moderate drought tolerance (Chivenge, Mabhaudhi, Modi, & Mafongoya, 2015). Taro features in several agroforestry systems as it is shade tolerant, making it ideal for mixed cropping systems, which typically feature trees (Chivenge et al., 2015).

Sweet potato (*Ipomoea batatas*) is climate resilient because of its suitability for low-input systems, drought tolerance and considerable environmental plasticity, which allow it to be planted and harvested at any time of the year (Motsa, Modi, & Mabhaudhi, 2015). It is also a nutrition-dense crop; for example, studies in sub-Saharan Africa established that the incorporation of orange-fleshed sweet potato varieties in children's diets led to an improved vitamin A status (Low et al., 2007).

4.3 | Economic viability

FSFs provide income opportunities for smallholders, and thereby improve livelihoods, on the basis of their higher nutritional and health value, and the fact that many are off-season crops. Being organic, these crops are also seen as safer or healthier. This is in addition to their adaptation to low-input agriculture, which will reduce the pressure on natural resource degradation (FAO, 2018).

By intercropping with cassava, finger millet offered 50% more income than that from cassava alone (Ravi et al., 2010; Swaminathan, 2005). This study demonstrated that NUS—which enjoy high adaptive advantages under marginal agroecological and edaphic situations—can enhance farmer incomes and food and nutritional security of local communities In India, farmers increased their income threefold by growing and selling millet. There was also more employment in the villages, especially for women, thereby enhancing their social status and self-esteem (Vijayalakshmi et al., 2010).

Quinoa is an excellent example of FSF that has become commercially important globally. For instance, Bolivia has emerged as a bright spot for quinoa in its region, with an average annual growth rate of 5% from 2005 to 2014, with an outstanding 6.8% increase in 2013. Farmers who once struggled to make ends meet are now earning substantial revenue from quinoa cultivation. Similarly, Peru has become one of the world's leading producers of quinoa. Peruvian quinoa exports have increased almost 10-fold since 2010, growing from USD 15 million in 2010 to USD 143 million in 2015 (Bellemare, Gitter, Kasterine, Obregon, & Zotz, 2016). Improvements in living conditions have subsequently improved livelihoods and education for mountain people in the Andes (FAO, 2018).

Some FSFs have high medical importance. For instance, drumstick has excellent medicinal properties—the leaves have a stabilizing effect on blood pressure and control glucose levels and are useful for treating night blindness as they are a rich source of vitamin A. Drumstick is also used to treat anxiety, diarrhoea, and inflammation of the colon, skin infections and scurvy. The leaves contain an ethanol derivative that can offer relief to individuals suffering from gastrointestinal disorders (Dandin, Harish, & Sasnur, 2014). The traditional medicinal value of plants can be further translated into high market value as a strategy to alleviate poverty.

FSFs growing in the mountains, with minimal fertilizer or pesticides and often considered organic, have higher market value as niche products. For instance, in India's Central Himalayan Region, female farmers are knowledgeable about many traditional agricultural practices that use no chemical inputs. Organized by agricultural microenterprises, 2,800 female farmers have increased supply and capitalized on the growing demand for organic products. Eighteen different types of traditional crops are marketed in Indian cities, including buckwheat, horse gram and foxtail millet. Recognizing its high quality, a Japanese company is purchasing foxtail millet in bulk for the preparation of baby foods (Khalid & Geetanjali, 2008; FAO, 2019).

4.4 | Local availability or adaptability

FSFs can help to preserve traditional knowledge and the cultural identities of indigenous people. Being locally available or adaptable is an important feature of FSFs that can contribute to sustainable agriculture development. Thanks to the indigenous people who acquired the capacity to conserve and manage natural and agricultural ecosystems, many traditional food systems have healthy elements based on local crop species having high nutritional values and being well adapted to climate change implications. Consequently, many FSF species and varieties have excellent desirable traits to both survive and thrive under challenging conditions (FAO, 2018).

Traditional farmers have domesticated, improved and conserved thousands of crop species and varieties over hundreds of years. They recognize that crop success is subject to the variability and unpredictability of weather conditions and the occurrence of diseases and insect pests. This precious traditional knowledge is acquired through frequent interactions with the local environment, driven by the need to pursue subsistence strategies for food and economic provision, and is often transmitted within communities. Abundant evidence shows that indigenous people have, over the years, acquired traditional knowledge in the selection of traditional crop varieties and new varieties/landraces that could adapt more easily to climate change. For instance, there is a dependence on finger millet in Northern India—as the rainfall has declined to 300 mm in recent years across the region, the finger millet varieties grown and conserved by farmers have shown excellent drought resistance and have therefore remained unchanged. This suggests that these varieties have sufficient adaptability to enable farmers to cope with periods of significant rainfall shortages (Chivenge et al., 2015).

As traditional knowledge associated with FSFs is often undocumented or hidden because of the isolation of areas and language barriers, there is a need to proactively tap into this knowledge to understand the various traits of local FSF species and varieties. This means they can be improved and further adapted to local farming systems. Meanwhile, building knowledge about traditional FSF crops should encourage local landrace conservation and production, local seed fairs, community seed banks, and community-based conservation and adaptation (Chivenge et al., 2015; FAO, 2018).

5 | DISCUSSIONS: PROMOTING FSF PRODUCTION, MARKETING AND CONSUMPTION

From a food system perspective, agriculture and food systems need to be transformed to become more diversified, nutrition-sensitive, climate resilient, economically viable and locally adaptable. FSFs can play a significant role in transforming these systems if they are mainstreamed. Tapping into the opportunities that FSFs offer for achieving Zero Hunger and poverty reduction needs to focus on the identification and prioritization of NUS that can be potentially become FSFs in terms of production, post-harvest and processing, marketing and consumption, and links to markets. Overall, the emphasis should be on building capacity for FSF products at each development stage of the food system, that is, prioritization, production, post-harvest and processing, marketing and consumption, and connecting all stages of the food system to minimize transaction costs (FAO, 2019).

A holistic food systems approach for FSF is as follows (Figure 6):

1. Prioritization: Identify and prioritize NUS to be potentially FSFs.
2. Production: Increase the production of targeted mountain FSFs in farming systems adaptable to various agroecological zones.
3. Processing: Improve the efficiency of post-harvest and processing of FSFs.
4. Marketing: Promote the distribution and marketing of FSFs.
5. Consumption: Increase the demand for FSFs among consumers by increasing awareness and knowledge on their multidimensional benefits, including nutritional value.

5.1 | Prioritize FSFs

Identify FSFs by following the established four-dimensional criteria to ensure sustainability: (a) nutrient dense, (b) climate resilient, (c) economically viable, and (d) locally available or adaptable. By doing so, farmer communities could produce sufficient, nutritious and safe FSFs for themselves and gain economic benefits from marketing surplus agricultural produce and services, while promoting conservation and the sustainable use of biodiversity and ensuring environmental sustainability.

5.2 | Increase production of FSFs

To increase FSF production, it is important to conduct research and development on FSFs, especially the development of improved varieties that can be integrated into various farming systems and adapted to local agroecological zones. Meanwhile, it is important to build the capacity of smallholder farmers to grow FSFs to ensure that they have surplus FSFs for household consumption and extra to sell to markets. Capacity building will require improvements in production efficiencies, by optimizing resource use and maximizing outputs, to sustain production and potentially make FSFs more affordable to consumers.

FIGURE 6 Development stages of food systems for Future Smart Food

5.3 | Processing FSFs

Processing FSFs is the transformation of agricultural products into food, or from one form of food to another. Food processing ranges from grinding grain, making raw flour, home cooking and making jams and pickles to complex industrial methods used to make convenience foods for direct consumption. It includes post-harvest, processing, packaging and labelling to make the FSFs more convenient, accessible and informative with nutritional panels. These activities result in value-added products that can reduce food losses along the value chain and enhance smallholder farmer income.

5.4 | Marketing: Upgrade market chains

The process of introducing new products to the market connects production, processing, distribution, marketing and consumption. Good marketing should cover advertising, promotion, public relations and connection to market channels. Because of the physical isolation and limited resources of mountain communities, who are severely affected by low levels of education, there is limited knowledge and information on how to market products. Policymakers, especially local governments, should play a proactive role in the coordination of stakeholders to help indigenous people to develop market-oriented strategies for the sustainable development of FSFs, including the expansion of FSF markets through fair trade and mountain product promotion. Advanced technical means could be used, including e-commerce, to overcome the barriers of geographical isolation for the promotion of FSF mountain products.

5.5 | Increase demand for FSFs

Increasing the demand for FSFs could be the driver for transforming agriculture and food systems, which will benefit consumers, smallholder farmers and other value chain actors. The demand for FSFs can be increased by increasing consumer and smallholder farmer awareness of the multidimensional benefits of consuming FSFs. This requires more information on FSF nutrition and preparation, and techniques to access markets through processing and other value additions. Establishing trusted brands and changing consumer perceptions of FSFs is vital to bring FSF mountain products to market. Current research findings and knowledge on FSF need to be disseminated through various media, local agencies, newsletters and advertisements to promote the consumption of FSFs.

5.6 | Creating an enabling environment for promoting FSF production, marketing and consumption

Governments need to move away from the intense focus on staple crops only and tap into the enormous potential of alternative crops that are nutritionally dense and climate resilient, as well as locally available. This is especially meaningful for the rural poor, who suffer the most from production and nutrition gaps, as well as shocks and uncertainties. One should not forget that traditional food systems in Asia have developed over hundreds of years, featuring an abundance of foods that were nutritionally dense and climate resilient: Promoting these alternative options offers greater yield increase potential and an opportunity to diversify dietary patterns and generate income for the rural poor. Although these alternative crops were often traditionally grown by local farmers, there have been no incentives to maintain or increase production (incentives were mostly geared towards rice production). It is time to rediscover these hidden treasures for the rural poor (FAO, 2018).

6 | CONCLUSION

Despite impressive progress, hunger, food insecurity and malnutrition are still significant problems in the Asia-Pacific region. Over-reliance on staple crops is a leading cause of persistent malnutrition coupled with low dietary diversity in Asia. NUS have a central role to play in the fight against hunger and malnutrition, but they are currently overlooked. There are four-dimensional benefits of FSF and their potential contribution to achieving Zero Hunger: nutrition, climate resilience, economic potential and local relevance. From a food system perspective, transforming agriculture and food systems into more diversified, nutrition-sensitive, climate-resilient, economically viable and locally adaptable systems is the key to harnessing the potential of FSFs, particularly if they can be mainstreamed. To tap into the opportunities that FSFs offer for agriculture achieving Zero Hunger, more attention needs to be given to both production and consumption. Identifying which species are appropriate is an initial step from a food system perspective. Continuous efforts should be given to promoting FSFs in terms of production, post-harvest, and processing, marketing and consumption. Government leadership will be indispensable to this end. Creating an enabling environment across value chains—to promote sustainable production, processing and consumption of FSF—is essential for achieving Zero Hunger.

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CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

CONTRIBUTIONS

XL and KHMS designed and performed the research.

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APPENDIX A: PRIORITY-SETTING EXERCISE ON NEGLECTED AND UNDERUTILIZED SPECIES: METHODOLOGY AND PROCESS

Priority-setting exercise

How to tap the high potentials of neglected and underutilized species (NUS) that are widely available in selected countries? It started with scoping, identification and prioritization of NUS. Food and Agriculture Organization of the United Nations (FAO), in collaboration with the University of Western Australia, International Center for Agricultural Research in the Dry Areas (ICARDA), International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), M S Swaminathan Research Foundation—Leveraging Agriculture for Nutrition in South Asia (MSSRF-LANSA), Chinese Academy of Tropical Agricultural Sciences—Tropical Crops Genetic Resources Institute (CATAS-TCGRI), Mahidol University, Australian Centre for International Agricultural Research (ACIAR), International Centre for Integrated Mountain Development (ICIMOD), Crops for the Future (CFF), as well as national research institutes, conducted an interdisciplinary priority-setting exercise that is composed of three phases (Figure A1):

1. Stage 1: scoping
   - Prepare a preliminary scoping report on the availability of NUS at national level.
   - Share the preliminary scoping report for comment.
   - Review the report by international institutions (prior to the expert consultation).
2. Stage 2: expert consultation
   - Validate the preliminary scoping report on NUS in the selected countries.
   - Rank high-potential NUS based on established priority criteria.
   - Identify 5–6 NUS crops per country.
3. Stage 3: geographic information system (GIS) mapping
   - Map high-potential NUS according to their geographical availability/prominence using GIS.
   - Prepare the GIS reports on selected crops per country.

Objective of expert consultation

The objectives of the Regional Expert Consultation were to

a. validate the preliminary scoping report on crop-related NUS in the selected countries,
b. rank and prioritize high-potential NUS based on established priority criteria,
c. identify 5–6 crop-related NUS per country and
d. strategize to enhance productions and the utilization of the selected crops in local diets.

Target food crops

It is proposed that target food crops focus on the following groups: cereals, roots and tubers, nuts and pulses, horticulture and others.

Priority criteria

It is proposed that NUS be assessed according to the criteria as follows:

(a) Nutrition	➢ Nutritional value and health benefits
(b) Production practice	➢ Local knowledge, availability and seasonality ➢ Productivity, intercropping and competing from other crops ➢ Processing ➢ Agroecology
(c) Ecological	➢ Adaptation to local climate and soil types
(d) Socio-economic	➢ Cultural acceptance and consumer preferences ➢ Access to market and potential income generation

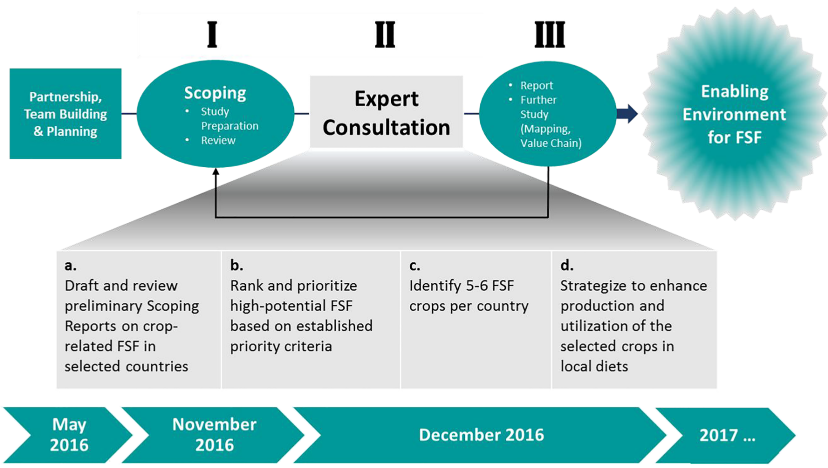

FIGURE A1 Regional priority setting on scoping, prioritizing and mapping of neglected and underutilized species. Future Smart Food

Partners and contributors

To conduct this comprehensive and interdisciplinary analysis, FAO built partnership with a number of international and national partners with expertise in relevant disciplines:

1. International partners:
   - FAO Special Ambassador for International Year of Pulses 2016
   - ACIAR
   - Bioversity International
   - CATAS-TCGRI
   - CFF
   - ICARDA
   - ICIMOD
   - ICRISAT
   - International Tropical Fruits Network (TFNet)
   - MSSRF-LANSA
   - Mahidol University, Thailand
   - The University of Western Australia (UWA)
   - The Akshaya Patra Foundation, India
2. National partners:
   - Bangladesh Agriculture Research Institute (BARI)
   - Cambodian Agricultural Research and Development Institute (CARDI)
   - Department of Agriculture, Ministry of Agriculture and Forests, Bhutan
   - Department of Agricultural Research (DAR), Myanmar
   - National Agriculture and Forestry Research Institute (NAFRI), Lao PDR
   - Nepal Agriculture Research Council (NARC)
   - Plant Resources Centre (PRC), Vietnam
   - Uttar Banga Krishi Viswavidyalaya (UBKV), West Bengal, India

APPENDIX B: GUIDELINES FOR THE PREPARATION OF A PRELIMINARY SCOPING STUDY ON CROP-RELATED NEGLECTED AND UNDERUTILIZED SPECIES

Background

Malnutrition is still prevailing in Asia and the Pacific region. To tackle its underlying causes, it is important to address the problem from different angles and link production, consumption and nutrition perspectives within a holistic food system approach. In this regard, the study focus will be on crops within the abundance of neglected and underutilized species (NUS), excluding mainstream cash and staple crops such as rice, maize and wheat. Crop-related NUS feature multiple benefits and offer a huge potential to diversify both agricultural production and dietary consumption, as well as strengthening natural environments. In the future, they will play a pivotal role in addressing malnutrition.

Objective

The objective of this preliminary scoping study is to assess the availability of high-potential NUS crops in selected countries in South and Southeast Asia and evaluate their potential from a nutrition, agriculture, ecological and socio-economic perspective at the national level (see Priority Criteria, Appendix A). The outputs shall be compiled in a comprehensive report that facilitates the validation of an overall picture on crop-related NUS and will help to identify and prioritize their promotion for every country in the region.

Requirements

1. Available crop-related NUS in each country shall be listed in Appendix B and sorted into the assigned food groups, which are cereals, roots and tubers, nuts and pulses, horticulture and others (fruit trees, etc.). In case the number of identified NUS exceeds the rows displayed, please insert additional space for your findings.
2. After available target crops have been listed, national experts shall assess the listed NUS based on the information available in their field and their national experience (e.g. nutrition expert in Cambodia assesses NUS in Cambodia from nutrition perspective). Please note that for each priority criterion, a separate Excel sheet is provided.
3. Each ministry/expert/institute may fill in additional information according to your knowledge.
4. Ensure that all relevant sources are tapped and that an integrated set of information is available after the scoping. Make as much use as possible of available data, studies and reports and fill information gaps by using informants and other methods to gather empirical data.
5. To ensure traceability of your findings and the aggregated information on crop-related NUS, please list your sources in the last Excel sheet 'Documentation'.
6. The listed NUS shall be ranked within each food group, and up to six priority crops per food group are to be highlighted according to national judgement. The judgement can be based on the given parameters (e.g. drought tolerance and area under cultivation) within each priority criterion, but you may also choose high-potential crops that are characterized by parameters beyond the set priority criteria. Also, if you wish to prioritize more than six crops, please proceed and substantiate why.
7. After completion, Appendix B will be shared with international experts from various disciplines for review and comments.

Crop-related neglected and underutilized species (NUS)				Priority criteria			
				Nutrition	Production practices		
				Nutritional value and health benefits	Local availability/seasonality	Productivity	Processing
Food group	English/local name	Scientific name	Accessions	Nutrient content and bioavailability	Dispersion and propagation, and harvest season	Agronomic issues and yield	Infrastructure and machinery
1. Cereals	Finger millet	*Eleusine coracana*	10,334				
2. Roots and tubers							
3. Nuts and pulses							
4. Horticulture							
5. Others							

Crop-related neglected and underutilized species (NUS)	Priority criteria			
	Ecology		Socio-economic	
	Climate tolerance	Agroecology	Access to market/income generation	Cultural acceptance/consumer preference
Food group	Drought/flood/heat tolerance and salinity	Ecological impact and benefits, e.g. irrigation, waste and soil fertility	Price and distance to market	Food taboos, religious restrictions and traditional uses
1. Cereals				
2. Roots and tubers				
3. Nuts and pulses				
4. Horticulture				
5. Others				

Crop-related neglected and underutilized species (NUS)			Priority Criterion 1: nutrition — Nutrient composition (per 100 g of edible fresh weight)													
Food group	English/local name	Scientific name	Water (g)	Energy (kcal)	Protein (g)	Fat (g)	CHO (g)	Crude fibre (g)	Ash (g)	Ca (mg)	Fe (mg)	Mg (mg)	P (mg)	K (mg)	Na (mg)
1. Cereals	Finger millet	*Eleusine coracana*													
2. Roots and tubers															
3. Nuts and pulses															
4. Horticulture															
5. Others															

Crop-related neglected and underutilized species (NUS)	Priority Criterion 1: nutrition													
	Nutrient composition (per 100 g of edible fresh weight)												Uses	
Food group	Zn (mg)	Cu (mg)	Mn (mg)	β-Carotene equ. (μg)	Vit. C (mg)	Vit. D (μg)	Vit. E (μg)	Vit. B_1 (mg)	Vit. B_2 (mg)	Vit. B_3 (mg)	Vit. B_6 (mg)	Folate (μg)	Food preparation	Medicinal
1. Cereals													Cooked/raw/as curry	Antiseptic
2. Roots and tubers														
3. Nuts and pulses														
4. Horticulture														
5. Others														

Crop-related neglected and underutilized species (NUS)			Priority Criterion 2: production practices					
			Local availability/seasonality					
					Harvest			
Food group	English/local name	Scientific name	Source	Seasonality	Time	Duration	Machinery	Intercropping with
1. Cereals	Finger millet	*Eleusine coracana*						
2. Roots and tubers								
3. Nuts and pulses								
4. Horticulture								
5. Others								

Crop-related neglected and underutilized species (NUS)	Priority Criterion 2: production practices						
	Local availability/seasonality	Productivity			Handling/processing		
		Yield (t/ha)					
Food group	Crop rotation	Wet season	Dry season	Estimated area under cultivation in ha (%)	Processing infrastructure/machinery	Perishability	Storage
1. Cereals							
2. Roots and tubers							
3. Nuts and pulses							
4. Horticulture							
5. Others							

Crop-related neglected and underutilized species (NUS)			Priority Criterion 3: ecology								
			Agroecology					Climate tolerance			
Food group	English/local name	Scientific name	Climate zone	Soil	Water requirement	Environmental benefits	Postharvest and waste management	Drought tolerant	Flood tolerant	Heat tolerant	Salinity tolerant
1. Cereals	Finger millet	*Eleusine coracana*				N fixation/prevent soil erosion		x			
2. Roots and tubers											
3. Nuts and pulses											
4. Horticulture											
5. Others											

Crop-related neglected and underutilized species (NUS)			Priority Criterion 4: socio-economic									
			Access to market/income generation				Consumption					Cultural acceptance
Food group	English/local name	Scientific name	Price	Distance to market/location	Market potential	Additional income opportunities	Daily	Once a week	Once a month	Special season	Other	Food taboos and religious restrictions
1. Cereals	Finger millet	*Eleusine coracana*			High/low							
2. Roots and tubers												
3. Nuts and pulses												
4. Horticulture												
5. Others												

Documentation of national findings on NUS

No.	Type of source	Bibliographical reference	Country	Year	Short description	Instruments used	Total no. of NUS identified	List of NUS	Link
1	IFAD publication (example)	Minor millets in South Asia learnings from IFAD-NUS project in India and Nepal	India and Nepal	2010	Documentation of results of the IFAD-funded project ‘Enhancing the Contribution of Nutritious but Neglected Crops to Food Security and to Incomes of the Rural Poor: Asia Component-Nutritious Millets’ implemented from 2002 to 2004.	Participatory surveys	6	Finger millet, little millet, Italian or foxtail millet, barnyard millet, proso millet and kodo millet	http://www.nuscommunity.org/fileadmin/templates/nuscommunity.org/upload/documents/Publications/2010_BhagMal_et_al_Asia_IFAD_NUS.pdf
2									
3									
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