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Mainstreaming Agrobiodiversity in Sustainable Food Systems

Scientific Foundations for an Agrobiodiversity Index

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Food biodiversity for healthy, diverse diets

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Food

KEY MESSAGES:

- Food biodiversity – the diversity of plants, animals and other organisms used for food, both cultivated and from the wild – is a critical element in response to global malnutrition, and it supports sustainable food systems.
- Food biodiversity reaches consumers through two principal pathways: (1) consumption via own production or gathering from the wild and (2) purchase of wild or cultivated species.
- The nutrient content between different species, or different varieties or breeds of the same species, can vary a thousandfold. This information can be used to maximize the nutritional adequacy of diets.
- Improved availability, accessibility, affordability and acceptability of food biodiversity are key factors for achieving better diets.

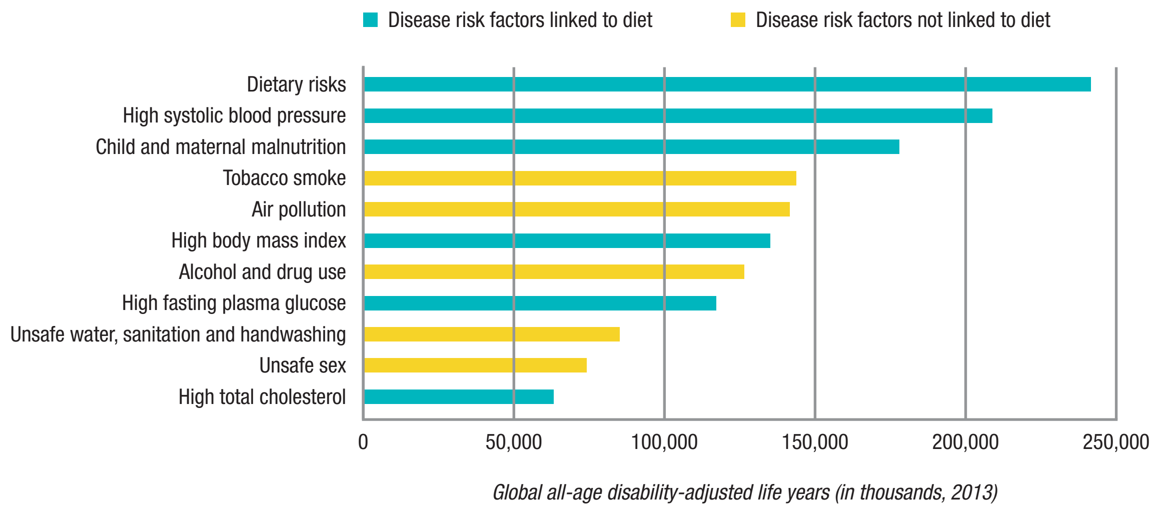
Introduction

One of the world's greatest challenges is to secure universal access to sufficient, healthy and affordable food that is produced sustainably. Current nutrition trends do not reveal a situation in which populations are well nourished, and the sustainability of how we produce, distribute and consume food is also a subject of concern. Serious levels of both undernutrition and overweight/obesity are reported for 57 out of 129 countries (1). Two billion people are overweight or obese, while two billion people lack essential vitamins and minerals needed for adequate nutrition. Malnutrition in children, which is in part linked to insufficient diets, is the underlying cause of half of all deaths among under-fives (2). Often malnutrition extremes, such as stunting in children and overweight adults, occur concurrently. Countries experiencing multiple forms of malnutrition, including under-five stunting, anaemia in women of reproductive age and adult overweight, are considered the new normal (3). At the same time there is an alarmingly fast-paced increase in non-communicable diet-related diseases (e.g. diabetes, hypertension) (4). One of the principal causes of these multiple burdens of malnutrition is poor diet. Diet-related factors are now the number one risk factor of morbidity and mortality globally (4) (Figure 2.1).

The economic toll of poor diets is also rising. The loss attributable to diet-related chronic disease has increased from 0.3–2.4% of gross domestic product (GDP) in Asia in the late 1990s to 11% in Africa and Asia in the 2010s (1). Improving diets is therefore an important health and economic goal for all countries.

Connected to the problem of addressing all forms of malnutrition is the issue of the environment. Sustainability issues within the food system relate to how we currently produce, transport, package, handle and consume food, including food waste. Our current food system is a major contributor to large environmental impacts, including biodiversity loss, greenhouse gas emissions, contamination and shortages of water, ecosystem pollution, and land degradation (6–9). Diets are influenced by the food system and its political, legal and institutional environment (10). When seeking to improve diets, a focus on food systems and the food environment is therefore key, particularly as regards the availability, accessibility, affordability and acceptability of healthy, sustainably produced food choices (3, 5). There is increasing evidence that both health and environmental benefits can be achieved by changing dietary patterns. Such a win–win is possible by transitioning toward more plant-based diets in line with standard dietary guidelines (11). Doing so could

FIGURE 2.1 – Diet-related risks are among the top eleven risks driving the global burden of disease



Source: Global burden of disease study 2013 adapted (5)
Note: The graph shows global disability-adjusted life years (DALYs) attribuited to level 2 risk factors in 2013 for both sexes combined.

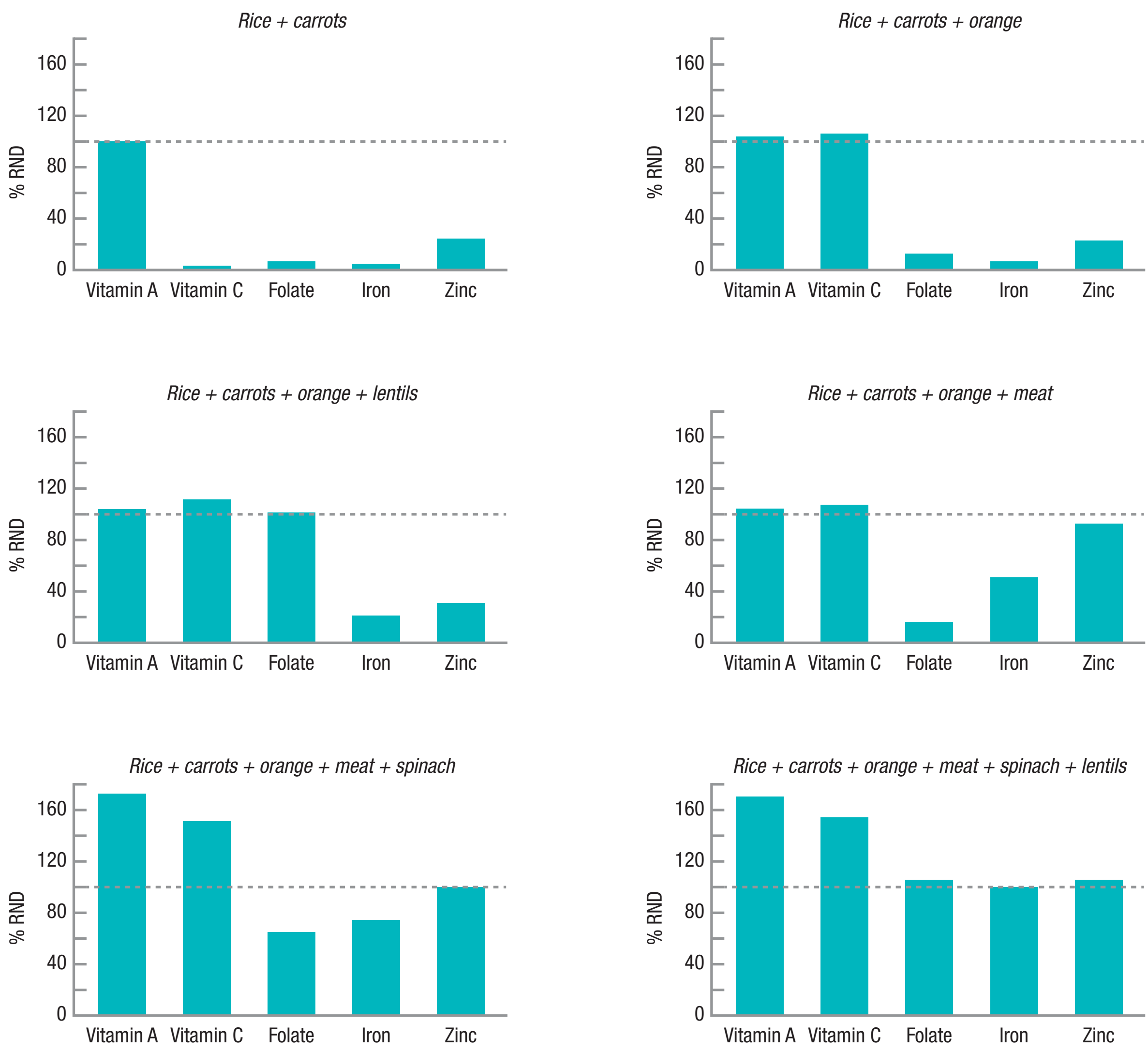
reduce both global mortality by 6–10% and food-related greenhouse gas emissions by 29–70% compared with a reference scenario in 2050 (11). Toward this end, recommended diets include a minimum of five portions of fruits and vegetables, less than 50g of sugar, a maximum of 43g of red meat, and an energy content of 2,200–2,300kcal per person per day, depending on the age and sex of the population. Tapping into the planetary wealth of diverse fruits, vegetables, pulses and grains, particularly nutrient-dense varieties among these food groups, holds the potential to generate the desired win–win scenario for people and the planet.

Food biodiversity and components of a healthy diet

In this chapter we use the term 'food biodiversity' as defined in a recent publication by FAO and Bioversity International (12) as "the diversity of plants, animals and other organisms used for food, covering the genetic resources within species, between species and provided by ecosystems". The contribution of food biodiversity to healthy and diverse diets can be measured at different levels. The highest level is food group diversity (e.g. cereals, dark green leafy vegetables and fruit), the next level is diversity within a food group (e.g. mango, banana and apple) and the lowest level considers diversity within a species (e.g. types of cultivated apple, such as Golden Delicious and Fuji, and also unnamed local and wild varieties).

Dietary guidelines around the world recommend a varied diet rich in fruits, vegetables, whole grains, nuts, seeds and legumes for optimal health (13). A diverse diet increases the likelihood of consuming adequate amounts of the full range of nutrients essential to human health (14). Figure 2.2 demonstrates this concept, showing how nutrient adequacy of the diet is improved as individual nutrient-dense foods are added to a meal.[i]

FIGURE 2.2 – Recommended nutrient density of a white rice diet improves with each addition of another type of food



Source: (15). RND = Recommended nutrient density

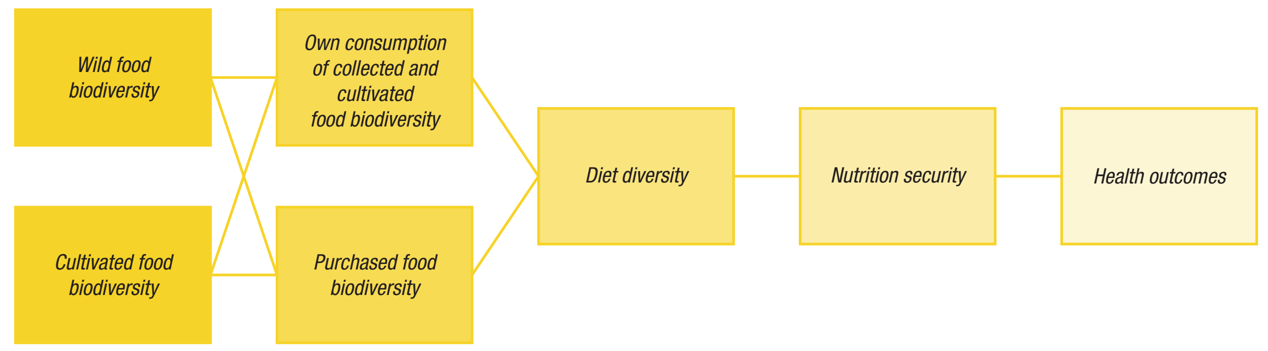
In the illustrative example in Figure 2.2, white rice is the first element of food biodiversity, carrot becomes the second food element, followed by orange, meat, spinach and lentils. Each of these foods represents one distinct element of food biodiversity. They are used collectively in the example to demonstrate how consumption of a diverse range of nutritionally distinct foods can fulfil nutrient needs. A common practice to simplify both measurement and messaging for consumers is to group foods with similar nutritional profiles into categories such as 'fruit', 'vegetables' or 'nuts and seeds'. The term 'diet diversity' is used in a general way to portray this concept. In many dietary guidelines, carrots and spinach might both be considered 'vegetables' Other definitions of food groups might categorize them in two different groups: vitamin A-rich vegetable (carrot) and dark green leafy vegetable (spinach). From the perspective of consumption of food biodiversity, they would be considered as two unique species in the diet.

Diet diversity is usually measured by counting food groups eaten in a certain time period. But this measure cannot provide a full picture of food biodiversity. For example, one can obtain information on the percentage of the target population that consumed 'fruit' in the previous 24 hours, but one would not necessarily know the intra-food group diversity consumed (e.g. banana, apple or orange) or how many species contribute to the food group and during which time periods of the year. It is even more difficult to gain information within the species, i.e. on the breeds, varieties or cultivars consumed.[ii] The implication of this is that most research uses dietary intake metrics based on diet diversity, which is not a perfect assessment of the full potential of food biodiversity, but does in an aggregate form represent consumption of diverse species.

This chapter will explore the evidence – as well as unmet potential for – food biodiversity, both cultivated and gathered from the wild, to improve healthy diet choices year round.

A balanced meal prepared during a cooking demonstration in Vihiga County, Kenya, by a group of caregivers trained in innovative dietary diversification. The meal consists of carbohydrate in the form of a rice–potato mixture, protein-rich beans, and a vitamin-rich mixture of vegetables (cowpea and amaranth leaves). Other ingredients used to enrich the meal are tomatoes, oil and iodized salt.
Credit: I.Otieno

FIGURE 2.3 – Two principal pathways leading from food biodiversity to diet diversity



Credit: Bioversity International

From food biodiversity to healthy, diverse diets: two principal pathways

Food biodiversity reaches consumers through two principal pathways: (1) consumption via own production or gathering from the wild, and (2) purchase of wild or cultivated biodiversity (Figure 2.3). We use these two principal pathways and the lenses of availability, accessibility, affordability, acceptability, gender and enabling environment to examine the contribution of food biodiversity to diet diversity.

The evidence for improving diets using food biodiversity

Food-based approaches to addressing malnutrition focus on food, rather than powders or pills, as the vehicle for supplying vital nutrients. Such approaches are considered among the most appropriate long-term and sustainable solutions to improving diets and nutrition (16). First, when we consume a food, we are consuming more than just the sum of its known nutrients, as foods may contain cancer-fighting antioxidants, fibre and many other beneficial substances that science is only beginning to discover. Second, there are important chemical interactions that occur when different food items are consumed together, such as the need for some fat in the diet to absorb vitamin A, or vitamin C-rich foods boosting the ability to absorb iron in foods. Synergistic interactions among nutrients and non-nutrient factors in different foods may convey further health and nutritional benefits (17–19). Third, certain foods, most notably fruits and vegetables, are now being promoted for intrinsic health benefits rather than focusing only on the known nutrients they provide (20). Last, a pure nutrient focus has led to some very misleading claims about 'healthy' foods (e.g. fortified breakfast cereals) and misguided messages to the public about the constituents of a healthy diet. For these reasons, a food-based rather than nutrient-driven approach is strongly advocated as an appropriate solution to alleviate the rise in diet-related non-communicable diseases, overweight and obesity (20).

Edible plant, animal and fish biodiversity can support nutrition through the availability and consumption of a wide variety of nutrient-rich foods (21, 22). Biodiversity has been explicitly recognized as a fundamental principle in recent versions of a number of national and regional dietary guidelines, including the Mediterranean Diet Pyramid (23), and the new Nordic (24) and Brazilian (25) dietary guidelines.

In addition to diversity across plant and animal species, there are important and significant nutritional differences within species. In the following sections, we first explore the evidence of the nutritional potential of within-species and between-species diversity for higher quality diets. We then discuss the linkages between cultivated and gathered diversity and diet diversity, and between food biodiversity in markets and diet diversity. We then summarize the evidence of policies and institutions that work to enhance the use of food biodiversity in food systems aimed at diet diversity and resilient production systems.

The nutritional value of food biodiversity

Food composition studies demonstrate that there can be important differences in nutrient content both between similar species (for example the difference in nutrient content of different kinds of fish in Figure 2.4) and within species (for example the difference between various varieties of banana or rice in Table 2.1). Knowing about nutrient content allows people to select and promote the most nutrient-dense species, varieties and breeds to use in farms, markets and public health campaigns in order to maximize the nutritional adequacy of diets.

Nutritional values between species

Research into fish consumption in Bangladesh provides a good example of the nutritional significance of these differences between species. In Bangladesh, although people had started eating more fish, there was a decline in intake of some essential nutrients. This was explained by the increase in production and consumption of farmed exotic fish species over non-farmed indigenous fish species, which contain higher levels of micronutrients (Box 2.1, 26).

Nutritional values within species

The nutrient content differences within crop varieties and animal breeds of the same species can sometimes be even greater than the differences between species (21, 27). For example, consumption of 200g of rice per day can represent from less than 25% to more than 65% of the recommended daily intake of protein, depending on the variety consumed (28). Table 2.1 shows the range of variation in some common species (rice, potato, banana) and some uncommon ones (pandanus, gac, breadfruit).

Significant nutrient content differences in meat and milk among different breeds of the same animal species have also been documented (29–31).

TABLE 2.1 – Examples of nutrient composition within varieties (per 100g edible portion, raw)

	Protein, g	Fibre, g	Iron, mg	Vitamin C, mg	Beta-carotene, mcg
Rice	5.6–14.6		0.7–6.4		
Cassava	0.7–6.4	0.9–1.5	0.9–2.5	25–34	<5–790
Potato	1.4–2.9	1–2.29	0.3–2.7	6.4–36.9	1–7.7
Sweet potato	1.3–2.1	0.7–3.9	0.6–14	2.4–35	100–23,100
Taro	1.1–3	2.1–3.8	0.6–3.6	0–15	5–2,040
Breadfruit	0.7–3.8	0.9	0.29–1.4	21–34.4	8–940
Eggplant		9–19		50–129	
Mango	0.3–1.0	1.3–3.8	0.4–2.8	22–110	20–4,320
Banana			0.1–1.6	2.5–17.5	<1–8,500
Pandanus			0.4	5–10	14–902
Gac					6,180–13,720
Apricot	0.8–1.4	1.7–2.5	0.3–0.85	3.5–16.5	200–6,939 (beta-carotene equivalent)

Source: (32)

BOX 2.1 – Nutritional value of small indigenous fish species

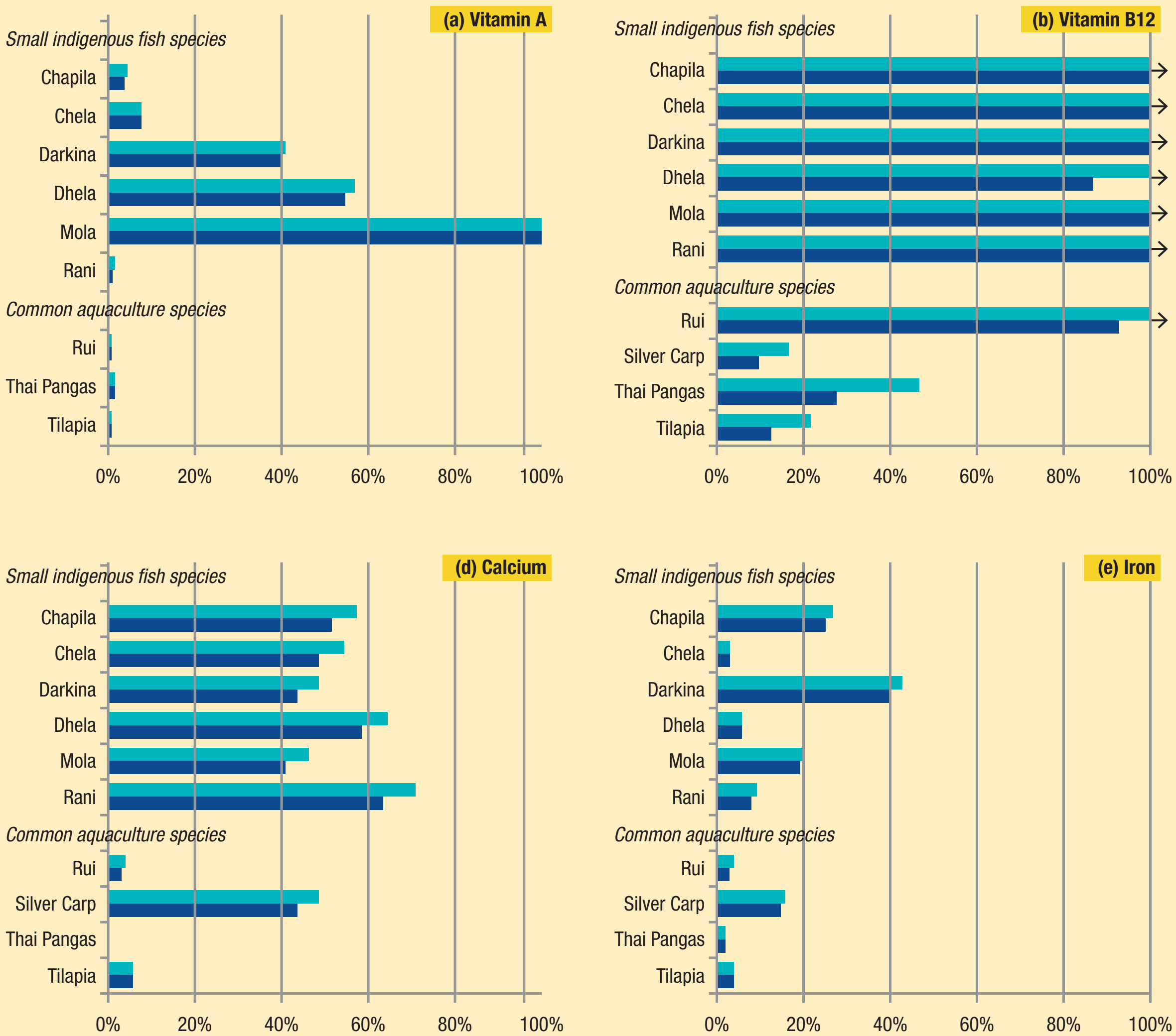
In many low-income countries, fish are an important animal-source food and means of dietary diversification, though the quantity and frequency of consumption can be low, especially among the poor. Fish are important not only for population groups who live close to water sources, such as marine coasts, lakes, rivers and wetlands, but also for those who live in areas far from water, as dried fish is commonly traded. The diversity of fish species found in water bodies can be great. For example, in Bangladesh, 267 freshwater fish species, 475 marine species and 24 introduced fish species have been recorded.

In Asia, led by China, aquaculture has expanded vastly in the last 30 years, with increasing fish production. However, the diversity of fish species used in aquaculture is small; in Bangladesh, species cultivated are mainly a few exotic carp species, tilapia and pangasius.

Using data from the Bangladesh Household and Income Expenditure Surveys from 1991, 2000 and 2010, it was shown that total mean fish consumption increased 30% over time, with the greatest relative increase (19%) among extremely poor households. Analyses of nutrient intake from fish showed increased intakes of animal protein and total fat, in parallel with increased fish consumption. However, the intake of iron and calcium decreased and intakes of zinc, vitamin A and vitamin B12 remained unchanged. These nutrient intake patterns over time reflect the shift to consuming a greater proportion of farmed fish and the lower nutritional quality of these farmed fish in comparison to non-farmed indigenous fish. Many small indigenous fish species have the potential to contribute significantly to micronutrient intakes of women and young children (Figure 2.4).

FIGURE 2.4 – Nutritional value of small indigenous fish species

Contribution (%) of selected fish species from Bangladesh to recommended nutrient intakes (RNIs) for pregnant and lactating women (light blue) and infants and young children (6–23 months, dark blue). Arrows represent contributions that exceed 100% of RNIs.
Standard fish portion sizes of 50g/day for women and of 25g/day for infants and children were used.



Source: (26)

The important finding is that differences in nutrient composition are statistically significant, sometimes with a thousandfold or greater nutrient content differences. For example, the content of beta-carotene (a precursor of vitamin A) in varieties of sweet potato can vary from 100mcg to 23,100mcg in 100g raw produce, and that of banana cultivars from 1mcg to up to 8,500mcg. Most notably, these differences can translate into meeting people's nutrient requirements, particularly for vulnerable individuals. For example, while the world's most commonly consumed banana, the Cavendish, contains almost no beta-carotene, the banana cultivar To'o, when ripe, contains 7,000mcg of beta-carotene equivalents (33), which meets the daily vitamin A requirement of both women and children.

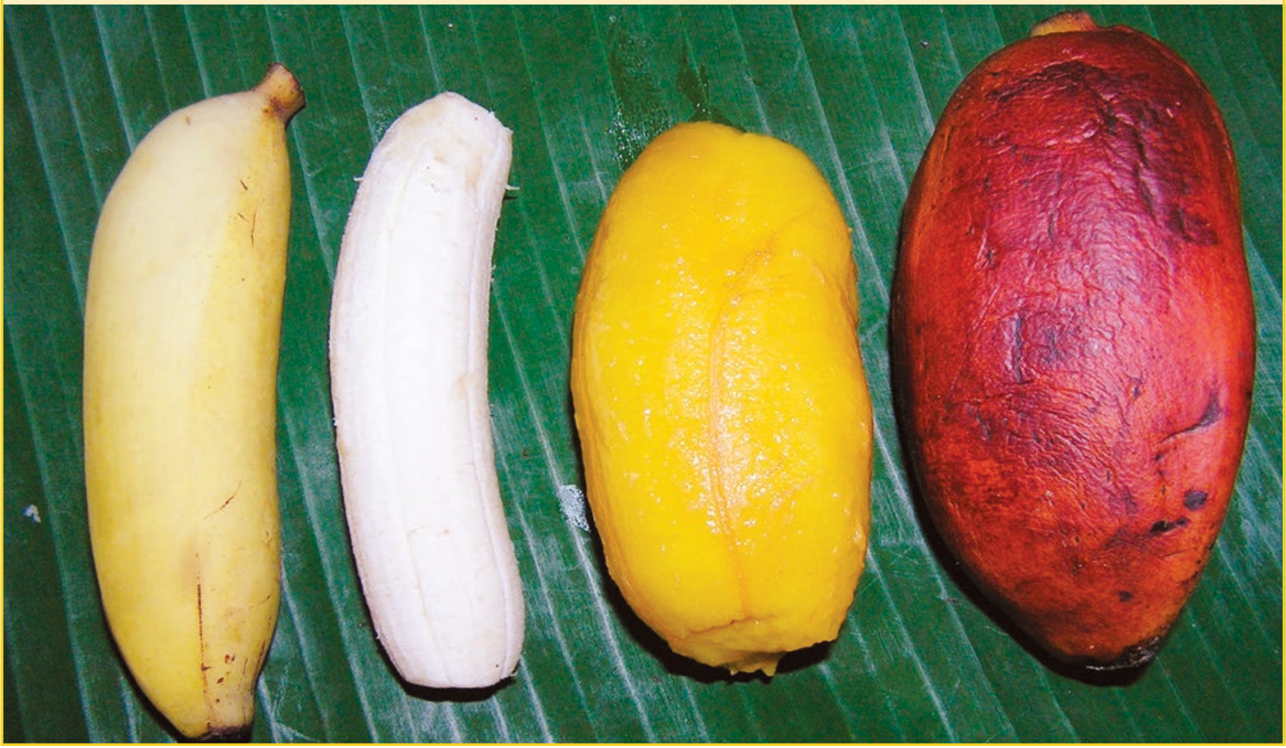
In some cases, the superior nutritional trait is visible. Figure 2.5 compares the Karat cultivar, one of a group of bananas commonly found in the Pacific known as the Fei group, with a white-fleshed banana. Another orange-fleshed banana, the Asupina had such high levels of carotenoids that a pre-school child could meet 50% of their vitamin A requirement by consuming one Asupina banana (c. 77g), whereas they would need to eat 1kg of Williams bananas to reach the equivalent amount of vitamin A (34). The nutritional distinction evident in the orange colour can be used by consumers to make better nutritional choices.

As yet we are only scratching the tip of the iceberg in relation to exploring the nutritional value of the world's food biodiversity. Despite many examples of within-species differences in nutrient composition, which could underpin successful food-based approaches, analyses often aggregate samples of the most commonly available cultivars and present them as mean values. This practice masks nutrient differences specific to the genetic diversity of a species and is a great handicap to researchers wanting to assess how food biodiversity can be used for better diets in countries around the world. However, increasing efforts are being made to disaggregate information to at least species level, including the definition of process indicators to measure progress in food composition and food consumption that measure the difference in composition between varieties of the same species (36, 37).

As more and better data become available, food biodiversity – covering thousands of varieties of fruits, vegetables, grains, legumes, animal breeds, fish, insects and fungi – is being recognized for its potential to improve the nutritional status of communities. The *Voluntary Guidelines for Mainstreaming Biodiversity into Policies, Programmes and National and Regional Plans of Action on Nutrition*, endorsed by the Commission on Genetic Resources for Food and Agriculture (CGRFA) in 2015, recognize that more data on composition and intake, for example on wild and underutilized species and animal breeds, are needed to determine the importance of food biodiversity in nutrition and food security (38).

FIGURE 2.5 – Comparing the nutritional composition of white and orange bananas

The orange Fei banana (right) known as Karat in the Micronesian island of Pohnpei contains 1000 times more provitamin A carotenoids than a white-fleshed banana (left).



Source: Musarama.org

Improving diet diversity through cultivated or gathered food biodiversity

How populations source food is complex and context-dependent. In particular, there are differences between urban and rural populations. Every individual household is likely to consume a varying mix of foods grown by themselves, gathered from the wild and procured from markets. Here, however, we separate out the evidence into the contribution to diet diversity of homegrown food biodiversity, wild food biodiversity and food biodiversity from markets.

On-farm food biodiversity and contribution to healthy, diverse diets

Food-based strategies can result in improvements in diet diversity (39–41). 'Nutrition-sensitive' agricultural interventions use food-based strategies to modify diets. Typical strategies include diversifying the household production system through home gardening, aquaculture and small-scale fisheries, small livestock rearing and dairy development programmes, as well as strategies to improve food processing, storage and preparation (42). Nutrition knowledge is key – strategies that are accompanied by a nutrition education component are more successful (39, 40). Many food-based strategies have the potential to diversify diets by promoting production of, and access to, a wider variety of food biodiversity.

Homestead food production in particular has been found to have a positive impact on nutritious diets. For example, a review of this production mode in four countries in Asia concluded that increasing the number of varieties of micronutrient-rich fruit and vegetables and animal-sourced foods available year round was one of the pathways that led to increased consumption of micronutrient-rich foods and improved micronutrient status (43).

Two recent reviews provide evidence of the positive link between biodiversity on farm or in the landscape and diet diversity (44, 45).[iii] The first review compared measures of agricultural biodiversity (crop species generally, sometimes also livestock species) to measures of diet diversity (counting food items or food groups over a certain time period). In five out of eight studies a positive association between farm diversity and diversity of the diet was reported; while in one study the relationship was positive for one country and not another (44). The second review, looking at the relationship between household-level food biodiversity and household- or individual-level diet diversity or quality, also found a positive correlation in 14 out of 15 studies (45). These associations were independent of household wealth or market access.

The significant peaks and troughs in household food availability are reduced when there is diversity in family farming activities. More biodiverse agricultural production systems (i.e. including more food groups in farming systems) (46) can enhance the availability of micronutrient-rich food varieties and improve nutritional outcomes all year round (47). In Malawi, researchers compared the strength of association between the number of food groups grown on farm and a diet diversity score for the entire household, for only children and for only women (all based on twelve food groups). Increasing the number of food groups grown was associated with a 0.12 increase in the number of food groups consumed by the farm household, 0.17 increase in food groups consumed by children and 0.11 increase in food groups consumed by mothers (48).

In another study from Malawi, the evidence suggests that more diversity grown on farms contributes to more diverse household diets, although the authors do highlight that the relationship is complex and may be influenced by a variety of socioeconomic factors. The specific nature of the farm diversity is also important. For example, a study in six districts of western Kenya found that on-farm production diversification correlates with household diet diversification, and also that livestock ownership, especially poultry, was more strongly correlated with diet diversity than crop production (49). Local initiatives that enhance traditional integrated livestock–crop systems of nutrient-rich vegetables and grains and the keeping of small animals (particularly indigenous chickens raised under extensive production systems) have been shown to have a positive impact on families' diet quality and consumption patterns, improving the diets of pregnant women and young children (Personal communication, Robyn Alders, Box 2.3).

Diversified farming systems, especially integrating small livestock such as poultry, sheep and goats, are sound interventions for enhancing diet diversity and nutrition for very poor, marginalized smallholders, as well as having added benefits as a risk management strategy against adverse shocks (49). Rural communities that rely on rain-fed crops often go through a hunger period or 'lean' season just before the major harvesting season, when their stored grains have been exhausted. Results from research in Zambia (Bioversity unpublished) found average diet diversity scores for both adults and children differed significantly across three seasons, and that average food group diversity was highest for adults in the middle of the identified hunger season. Similar findings of higher diet diversity scores – particularly of fruits and vegetables – during the lean season have been observed in rural Burkina Faso (50) and Kenya (51). Promoting fruit species which mature during periods of the year when other food supplies are limited can be a successful food and nutrition security strategy as well as a means to supply fresh fruit year round (Box 2.2). Similarly, integrated livestock–crop systems can be designed to maximize the availability of nutritious foods all year round especially during the lean seasons (Box 2.3).

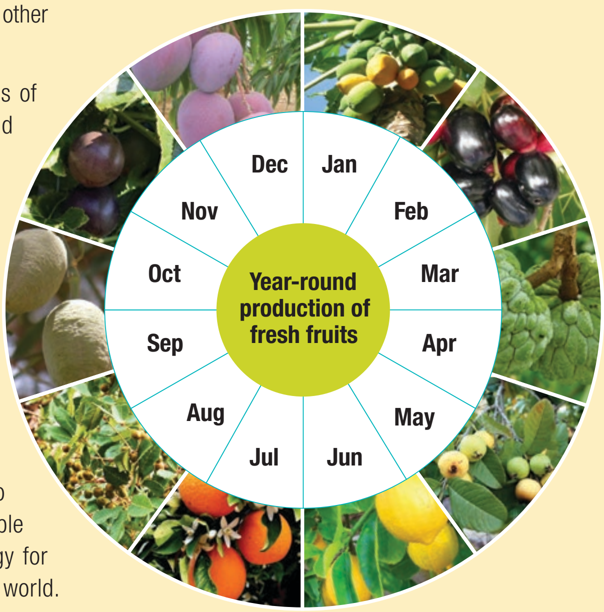
BOX 2.2 – The role of fruit tree portfolios in year-round access to fruit

Integrating fruit trees into mixed crop farming systems can provide year-round harvest of a variety of healthy, nutrient-dense foods. Fruits increase the nutritional quality of local diets, mostly due to their micronutrients (mineral and vitamins), but also macronutrients (protein, carbohydrates) and phytochemicals (e.g. antioxidants) (52). In addition, trees are resilient with regard to climate variability and their products can close hunger and nutrition gaps caused by the seasonality of common grain and pulse staples and other crops such as leafy vegetables.

'Fruit tree portfolios' are defined as location-specific combinations of indigenous and exotic fruit tree species that can provide year-round harvest of vitamin-rich fruits and, at the same time, fill 'hunger gaps' and specific 'nutrient gaps' when integrated into farming systems (53, 54). Fruit tree portfolios can enhance the diversity of fruits on farms and in food systems for increased consumption and better diets, while addressing seasonal fruit availability.

The fruit tree portfolio approach was piloted in two sites in Kenya: Machakos, Eastern Kenya and Kakamega and Siaya Counties, Western Kenya. The fruit tree portfolio for Machakos County is presented in Figure 2.6. Ten fruit species rich in pro-vitamin A and vitamin C were selected and combined in a portfolio for promotion in the county. The portfolio approach can be developed to include suitable, complementary vegetables, as well as annual, staple crops to provide for a 'diversified diet' approach. The methodology for developing fruit tree portfolios can be applied in any country in the world.

FIGURE 2.6 – Fruit tree portfolio for Machakos County, Kenya, showing year-round fruit harvest of vitamin A and C rich fruits



Contributing authors: Stepha McMullin and Ramni Jamnadass
Figure source: (54)

BOX 2.3 – Integrated livestock–crop systems are crucial to support balanced diverse diets throughout the year

Local initiatives, such as enhancing traditional village chicken–crop systems, can provide a sustainable solution to the ongoing nutritional challenges in Africa and Asia. Rural communities that rely on rain-fed crops often go through severe hunger periods just prior to the major harvesting season when their stored grains have been exhausted. By improving village poultry health and welfare, for example by vaccinating against widespread diseases, such as Newcastle disease, families have greater access to poultry meat and eggs, which are a source of high-quality protein, highly bioavailable micronutrients and income. Village poultry have the additional quality of being able to scavenge feedstuffs not typically consumed by humans. Poultry manure can contribute to increased soil fertility for the production of indigenous vegetables at the household level, further diversifying the range of foods eaten (55, 56).


Community vaccinators increase village chicken health and production by vaccinating them against Newcastle disease. Credit: R.Alders

Contributing author: Robyn Alders

Diverse, wild herbs for sale at the the 6th edition of the Alaçatı Herb Festival in Western Turkey.
Credit: Bioversity International/D.Hunter

Farm diversity is only one factor affecting diets. Data from Indonesia, Kenya, Malawi and Ethiopia found that the relationship between increasing production diversity and diet diversity is smaller compared with the effect of improving market access (57) (see Section on markets p36).

Wild food biodiversity and evidence of its contribution to healthy, diverse diets

The role of wild foods in diets has been explored at two levels: the first investigating the relationships between different landscape types and diet diversity; the second the relationships between wild food species and diet diversity.

At a landscape level, researchers, using remote sensing and satellite imaging, found an association between tree cover and diet diversity (44). Similarly, a significant positive relationship between tree cover and children's diet diversity was observed in 21 African countries, suggesting that children in Africa who live in areas with more tree cover have more diverse and nutritious diets (58). A similar approach in Malawi found that forest cover is associated with better health and nutrition outcomes in children and that children living in areas where there was a net loss of forest cover had less diet diversity and were less likely to consume vitamin A-rich foods (59). Ickowitz et al. (60) examined the relationship between different tree-dominated landscapes and consumption of micronutrient-rich foods in Indonesia and reported that areas of swidden/agroforestry, natural forest, timber and agricultural tree crop plantations were all associated with more frequent consumption of food groups rich in micronutrients, with swidden/agroforestry landscapes associated with the most frequent consumption of the largest number of micronutrient-rich food groups. As yet, the mechanisms behind these associations are unknown.

Recent reviews (27, 61) of the extent of wild biodiversity used as a food reveal the following highlights:

- Approximately 1 billion people around the world consume wild foods
- The mean use of wild foods by agricultural and forager communities in 22 countries of Asia and Africa (36 studies) is 90–100 species per location
- Aggregate country estimates can reach 300 to 800 wild edible species (e.g. India, Ethiopia, Kenya).

The extent to which this edible wild biodiversity contributes to diet diversity and nutrient intakes can vary considerably and, due to methodological limitations and differences across studies, is difficult to quantify. In some instances, wild foods can constitute a large portion of the diet. For example in Vietnam, wild vegetables contributed between 43% (Central Highland) and 75% (Mekong Delta, flood period) of the total weight of vegetables consumed (62). In other studies, despite documentation of an abundance of wild species traditionally used for food, dietary intake studies show actual consumption is limited (due to seasonality or small amounts of wild food consumed) (44). In Benin and the Democratic Republic of Congo, for example, a considerable number of wild edible plants were known by the local populations (61 and 77 species respectively), but the contribution to total dietary intake was relatively low due to low frequency of consumption (63, 64). A study conducted in rural South Africa found that not all of the available wild vegetables were consumed and, if they were consumed, the quantities were small (65).

Because of their resilience to harsh conditions, wild foods often act as safety nets or coping strategies in times of food shortage and famine. Studies have found that wild food consumption increases when stores of staple food crops decline (66, 67). For example, in the harsh lands of the Pamir Mountains, when the winter stores are dwindling and the new harvests are not yet ready, people collect and eat wild foods, such as wild rhubarb, purslane and mushrooms (68).

It is difficult to accurately assess the contributions of wild food biodiversity to diets and nutrition, due to the technical challenges of identifying the correct taxonomy of foods and measuring diet intake (22). The actual proportion of daily nutrient requirements supplied by wild foods relative to consumption of home-grown or purchased foods remains largely unknown (27). Information remains limited and fragmented (32) or of poor quality (69). Sometimes the challenge lies in the false dichotomy of distinguishing between wild and cultivated biodiversity, since many wild foods are actively managed in the wild, or introduced into gardens (61, 70).

Despite the methodological challenges in reviewing actual contributions of wild foods to diets, there is a huge potential for wild and neglected foods to contribute to diet diversity and nutrition. Many wild food species are richer in vitamins, minerals or macronutrients (fats and protein) than many conventional domesticated species that dominate agricultural or home-garden production (27, 61). For example, indigenous fruit trees (52), indigenous leafy vegetables (53, 71, 72) and wild plant and animal species (27) have higher nutrient content compared to their more widely cultivated exotic counterparts. In South Africa, for instance, four wild leafy vegetables (lambsquarters, sow thistle, black nightshade and nettles) were found to be good sources of protein, crude fibre, calcium, iron, manganese and phenolics (73). Nettles contained the highest concentrations of calcium, potassium, phosphorus and zinc, while a particularly high level of iron was observed in sow thistle.

A study in Baringo District, Kenya, demonstrated that wild foods have the potential to increase nutrient adequacy while reducing the cost of a nutritious diet, were they to be consumed in sufficient quantities to boost intakes of essential nutrients (74).

Many wild foods have been reported to have medicinal as well as nutritional uses. For example, the rare White *Garcinia* fruit, found in the forests of southern India, is highly valued in Ayurvedic medicine to treat severe gastric reflux (75). In the Pamir Mountains, safflower, purslane, black cumin, seabuckthorn and wild rose, among others, are used to treat common ailments (68). Wild foods often possess pharmacological substances that cultivated plants have lost during the process of domestication (70, 76).

Despite their value, the use of wild foods is declining (77). Increasing modernization and globalization are contributing to a loss of knowledge and decline in their use (77). The loss of indigenous knowledge has been recognized as one of the general factors negatively affecting biological diversity (78). Community health and extension workers tend not to have the necessary knowledge to promote the nutritional value of wild foods as a sustainable strategy to improve diet. Replacing traditional foods with a more homogenized range of species results in the loss of genetic diversity in traditional food species and a decline in cultural diversity. On the other hand, wild foods can represent an inextricable link between people and their lands, defining biocultural identity (61, 68, 76). It appears that cultural attachment to local culinary traditions and the appreciation of specific dishes in urban circuits can be, in some regions, sufficient to partially halt the erosion of traditional knowledge related to the use wild food biodiversity (78–80).

Wild foods are often excluded from official statistics on economic values of natural resources (61). A recent quantification of the economic contribution of wild foods, using data from almost 8,000 households in 24 developing countries across three continents found that 77% of households were engaged in wild food collection from forest and non-forest environments (81). The main role of wild food collection was found to be for household nutrition, with wild plant and animal foods contributing important sources of micro- and macronutrients. In addition to contributing directly to household consumption, wild foods are also traded in significant volumes around the globe. Households can use income from sale of wild food biodiversity to purchase nutritious foods (Figure 2.3). In southwest China, for example, over 280 species of edible vegetables are sold; trade in wild vegetables contributes 15–84% of cash income for certain groups, and the price for wild vegetables exceeds that of cultivated vegetables (27).

Introduced machines to ease the processing of quinoa and other traditional grains in Bolivia, a process that otherwise takes hours. Some highly nutritious grains are burdensome to prepare and so being abandoned in favour of easy-to-use crops. Reducing preparation times can put nutritious, traditional crops back on the plate.
Credit: Bioversity International/S.Padulosi

Considerations of gender in food biodiversity and nutrition

The role of women as custodians of food biodiversity is critical. In several regions and among different cultural groups, it is women who predominate as wild plant gatherers, home gardeners, plant domesticators, herbalists, seed custodians, informal plant breeders and farmers (82). By doing so, women are not only the main providers of household nutrition and health (83), but also managing and conserving most of the plant resources used by humans. Products from their gathering and gardening activities bring additional diversity to otherwise monotonous diets. Some experts consider women to be the nexus of the agriculture, health and nutrition sectors (84). Because of their domestic tasks (gardening, plant gathering, post-harvest preservation, storage and food processing), women maintain a close relationship with plants and have the greatest local plant knowledge (82). However, this knowledge is greatly undervalued as most of the activities occur within the domestic realm and the principal values of plant genetic resources are localized and non-monetary (82). Several studies (Southern Zimbabwe, Mexico) stress the important role of women and children in collection, processing and sales of edible insects (85, 86). The insects harvested by women or the income derived from insect sales tend to be used for household needs (87). Men and women also tend to have different knowledge about insects; for example in Niger women were able to name approximately ten more folk species of grasshoppers than men, as women play a larger role in collecting and preparing the insects (Groot 1995 in 87). While men are often more involved in hunting of game meat, in some cultures women are the primary retailers. A study in Kinshasa (DR Congo) found that 80% of bushmeat traders were women (88). One should not, however, make too many generalizations, as ecological and traditional knowledge and practices should be studied within their biocultural context.

Women's knowledge, education, social status, health and nutrition, and their control over resources are key factors that affect nutritional outcomes (77). Women's social and economic empowerment, often resulting from improved education or access to regular income, is key to addressing hunger and malnutrition (83). As early as 1999 it was shown that women's status and improvements in women's education are associated with positive impacts on child nutritional status (89). Different aspects of women's empowerment appear to have different effects on diet diversity and nutritional status for both mothers and children (90). For example, nutrition education interventions targeting caregivers with small children significantly increased caregivers' nutritional knowledge and improved diet diversity of the children involved (91).

Women also play a key role in food purchases. Their food choices take into account individual and household preferences and market factors, such as availability, accessibility and affordability. Interventions in the enabling environment need to account for this aspect, and targeted efforts to enhance nutrition knowledge and sensitize consumers regarding the importance of food biodiversity for diverse, healthy diets require a strong, albeit not exclusive, focus on women.

Considering the evidence above, a focus on the role of women in the production and use of food biodiversity is central for sustainable food systems as: (1) women are the main providers of household food and nutrition and have important, but undervalued, knowledge on agricultural biodiversity for food and nutrition, and (2) there is growing evidence that empowering women through education and/or income generation contributes to improving diets and nutrition. There is an important opportunity to document, validate, strengthen, share and transmit women's knowledge on agricultural biodiversity as a valid strategy to empower them to improve sustainability of diets, nutrition and health.

Improving diet diversity through food biodiversity purchased in markets

Rural households can meet a good part of their dietary needs through consumption of homegrown or gathered food biodiversity. Growing populations in urban and peri-urban areas, however, largely rely on purchased food. For this second pathway (Figure 2.3), they make use of a range of often informal market outlets, such as wet markets, street markets, traditional grocery stores and kiosks. At the same time, food is increasingly being purchased in supermarkets and hypermarkets, which are on the rise, particularly in Asia and Latin America (92). Along with the food environment around them, these market outlets drive food choice by signalling what is available, accessible, affordable and acceptable (1, 10). While the role of markets in improving diet diversity has not been empirically researched on a large scale (93), this section reviews existing evidence of diverse market outlets to make food biodiversity available, accessible, affordable and acceptable to low-income consumers in urban, peri-urban and rural areas.

Availability of food biodiversity in different markets

As an entry point to the food system, agricultural production and, to a lesser extent, food collected from the wild are key variables for determining how much food is available (volume, stability of production, seasonality), in what quality (nutritional value, food safety), and with what degree of diversity (food groups). Over the past four to five decades, profound changes have altered the global food system. World average availability of food energy (kilocalories) for direct human consumption reached 2,770kcal/person/day in 2005–2007, up from 2,411 kcal/person/day in 1969–1971 (94). While availability of food in general has increased, over the same period, the food offer in many countries has become more uniform. Lack of availability of food biodiversity is therefore the major factor that affects dietary choices (10). For instance, fruit and vegetable intakes do not reach the dietary recommended levels in many countries due to their limited availability in markets (95, 96). Availability of pulses, a nutritionally and culturally important diet component, has decreased globally (97). At the same time, the shares of meat, fish and eggs, in total protein availability per capita, have steadily increased over time (98). The expansion of supermarkets in Latin America and Asia and, to a lesser extent, Africa, has been a major factor driving availability of these foods (99, 100). In South Africa, for example, healthier food choices are available in supermarkets, but many towns only have small food stores with a limited selection of healthy foods (101). Food availability is also limited by seasonality, which proves particularly challenging for the most vulnerable populations (102). Even in emerging economies, such as Malaysia, seasonal household food shortages are due to unavailability of food in the market (103). Traditional, often informal and small-scale market outlets buffer such shortages and contribute to year-round availability of food biodiversity, but systematic evidence of the magnitude and quality of this buffering role across countries is lacking.

Relationship between market access and diet diversity

Availability of food biodiversity is closely linked to market access, both from a producer's and a consumer's perspective. Access to markets can be differentiated according to the type of market outlet (e.g. formal vs. informal, large-scale vs. small-scale). In addition, local, regional, national and international markets are increasingly connected, and changes in higher-level markets have repercussions on lower-level markets over the short and medium term. For example, while the share of imported foods (higher-level market) in many African countries is still fairly low, imports of fairly homogeneous foods in Asia and Latin America are growing rapidly, increasing the risk of crowding out producers and traders of locally produced, biodiverse foods in lower-level markets.

From an urban consumer's perspective, the informal sector plays an important role in many food retail markets and the diversity of informal market outlets allows for a diverse offer of food choices based on food biodiversity. In Kenya, for example, a country with a growing number of supermarkets and a relatively well developed formal food sector, high-income households may buy all types of food in a supermarket, while low- and middle-income households mostly use supermarkets to buy processed foods, but purchase fresh fruit, vegetables and other food from traditional *dukas*, followed by open markets, butcheries and kiosks (104). A similar preference has been observed for livestock products, such as milk, as Kenyan households prefer to buy unpasteurized raw milk from informal retailers, who sell raw milk at almost half the price of the formal retailers, rather than buying more expensive pasteurized milk (105).

From a rural producer's perspective, market access has been found to be positively correlated with diet diversity. In a comparative assessment across five studies, greater market access was associated with higher diet diversity or quality, with positive relationships for: selling higher share of production, devoting more land to market crops, and access to public or own transport; and negative relationships for: reliance on own production for consumption, distance to nearest road or market, and rural location (45). In Mexico, proximity to urban areas paired with opportunities to participate in larger and differentiated markets were found to be linked with higher on-farm diversity levels, reflecting that greater market opportunities can bring about diversification rather than specialization (106). In Benin, high diversity of markets increased the consumption of diversified diets among mothers, accounting for 65–80% of all the variation of foods consumed by mothers (106). As a result, mothers consumed more than the threshold amount of grains, roots and tubers, as well as meats, fish and seafood (106). In Malawi and Ethiopia, better market access by producers increased the level of purchased food diversity (107).

These examples show that a positive relationship can exist between market access and diet diversity – from a consumer's perspective in terms of having physical access to food biodiversity and, from a producer's perspective, through opportunities for generating income that can be used for food purchases, complementing the consumption of self-produced food. In a study from Malawi, it was concluded that improving access to markets, along with productivity-enhancing inputs and technologies, is a more promising strategy to improve diets in smallholder farm households than further increasing production diversity (48).

Affordability of a more diversified diet

In addition to availability and access, affordability of healthy food is a key determinant for achieving better diet quality. While in theory healthy eating does not need to be more expensive than unhealthy food habits, there is evidence from various countries that moving towards healthier diets comes at a price (see Box 2.4). In rural South Africa, for example, a typical 5-member household would need to increase food expenditures by more than 30% of the total household income to eat a healthier diet (101). In South Asia, when the price of staple foods goes up, poor consumers are more likely to consume less of the heathier dietary components and tend to consume cheaper and lower-quality foods (108).

BOX 2.4 – Cost of a healthy diet

In most rich countries, the mean cost difference between healthy and unhealthy diets is about US$10.50/week (109). Other studies show that in the UK the cost of a healthier diet is double that of the least healthy one (110). In Ethiopia, Myanmar, Tanzania and Bangladesh, the average minimum cost of a healthy diet ranges from US$0.72 to US$1.27/day (111), and in South Africa a healthier diet costs 69% more than an unhealthy one (101). A 10% increase in price of fruits, vegetables and pulses has been predicted to result in 7.2% lower consumption in poor countries, 6.5% lower in middle-income countries and 5.3% lower in rich countries (112).

Evidence on affordability of healthy food suggests that a principal way to increase consumption of diversified diets is to lower their relative price (10), particularly as regards fruit and vegetables (113, 114). While this sounds like a straightforward solution, there are some caveats to this: (1) if consumer prices are to be lowered, farm-gate prices for food biodiversity might be put under further pressure, crowding out poor smallholder households, (2) strong collaboration is needed among various stakeholders in value chains for biodiverse products to ensure higher efficiencies, and (3) significant public and private investments in infrastructure (e.g. road network, storage facilities, cold chain) are needed to reduce post-harvest losses.

Acceptability of a more diversified diet

Even if healthy food is readily available, accessible and affordable, there may be social and cultural reasons for low-income consumers to prefer less diverse or less healthy diets. Evolutions in diets are influenced by higher income per capita, food prices, individual and sociocultural preferences, and the development of the cold chain (98). Acceptability is linked to perceptions of taste, palatability, prestige, convenience and cultural factors, among others. For example, there is a striking increase in demand for convenience, often highly processed foods. In East and Southern Africa, the market share of such foods has risen to one-third of the purchased food market, with little differentiation between rural and urban areas (31% vs 35%) (115). Acceptability of food biodiversity can be shaped by sensitization, education and capacity building. For example, 45.2% of households in Kenya who had participated in awareness-raising activities about the nutrient content of some 40 different species of traditional leafy vegetables still reported increased consumption ten years later (116).

The types of foods that urban and rural dwellers consume often differ significantly. While it is difficult to determine the role of preference relative to that of access and affordability, urban and rural food preferences are not alike. In Mozambique, for example, urban and rural dwellers consume comparable amounts of maize flour, but urban dwellers consume three times as much rice, much less cassava flour, and negligible amounts of sorghum flour compared with rural dwellers. Urban dwellers also consume more meat, chicken and fish, especially fresh fish. The types of vegetables and pulses they consume also differ significantly: urban consumers prefer butter beans, tomatoes and Portuguese spring greens, while rural consumers purchase more peas and cassava leaves (117). Similar differences in preferences have been observed elsewhere in Africa, for example in Niger, Mali and Burkina Faso (118), Burundi and South Africa.

In addition to rural–urban differences in food preferences, the transformation of the food system in many countries is likely to have important implications for food biodiversity in markets and produced on farms. In India, for example, during a first stage of food system transformation (income-induced diet diversification), consumers replace inferior goods with superior foods, for example by substituting traditional staples, such as rice. In a second stage (diet globalization), there is a much more marked increase in the consumption of proteins, sugars and fats (119). These transformations may have significant implications for food biodiversity in markets, since foods rich in proteins, sugar and fat can be efficiently produced by larger farms and food processors without requiring high diversity of animal and plant species or varieties. Such agri-food value chain actors also rely on a limited number of retail outlets, particularly supermarkets or hypermarkets.

Maintaining or expanding market diversity is therefore critical for linking food biodiversity with the diversity that ends up in people's diets. Factors which mediate between market and diet diversity include the status of food, norms, advertising, food quality and perceived value (price–quality relationship, convenience). People in urban areas tend to eat more fast, street and highly processed foods because they are convenient, affordable and tasty (120). Advertising increases the desirability of foods, and hence influences food choices (10). Consumers' knowledge, through educational campaigns, influences their attitudes towards consuming food types. African traditional vegetables, for example, have been marketed with emphasis on their nutrition qualities which helped change consumers' perception that such crops are low-status (121). Quinoa, an American native crop with high nutritional qualities (122) that provides reliable yields also under extreme growth conditions (123), has long been consumed by the rural Andean population, while the region's urban consumers took it as a low-status food. When consumers in the global North, stimulated by promotional campaigns, started to increasingly consume quinoa in the 1990s, local producers received positive price signals. With growing demand in North America and Europe, along with the consumers' willingness to pay premium prices, quinoa production became more prestigious. Not only is it now consumed in many parts of the world, but there is also growing awareness in its centres of origin, like Bolivia, regarding the value of the Andean crops both for local uses and for marketing in global value chains (124). Increasing the visibility of and adding value to local food biodiversity have proven to be instrumental for boosting its consumption. In combination with added value, the enhanced use of food biodiversity through improved practices is expected to increase food supply and make countries like Nigeria less dependent on food imports (125). This calls for integrated approaches that combine agronomic and market interventions, with the aim of boosting the availability, accessibility, affordability and acceptability of food biodiversity.

Creating enabling environments for healthy diets based on food biodiversity

Recent high profile reports starkly remind us that our agriculture and food systems are not delivering optimal nutritional outcomes, and draw attention to a number of key opportunities and recommendations necessary for the transformations required to reverse this (5, 7). Current production sector policies, public and private investments and related programmes all too often focus on maximizing productivity and income-generating potential, but give little consideration to how each sector might contribute to improved diets and nutrition (126). As a consequence, agricultural and food investment policies have become divorced from nutrition policies, a disconnect that needs to be urgently corrected (127). Agricultural and food policies have proven resistant to change due to a number of reasons including silo and short-term thinking (128). The development of better food planning processes and joined-up food policies at multiple levels have been identified as two recommendations to break down this resistance (7). Though still few, there are a growing number of instances where cross-sectoral approaches are contributing to joined-up policies that are effectively linking agriculture with steps to tackle malnutrition and the impacts of unhealthy diets. An area of considerable convergence in terms of recommendations and opportunities to transform agriculture and food systems for improved diets, identified in three recent, high level reports (5, 7, 129) addresses a group of common and related themes: sustainable and healthy food sourcing, institutionalizing high-quality diets through public sector purchasing power, public procurement to support local agroecological produce, and the development of short supply chains. In each case agricultural biodiversity can be used to support the desired transformation. Already there are useful examples that can be replicated and scaled up.

For example, the *2014 State of Food Insecurity in the World* highlights the significant strides that some countries, such as Brazil, have made in reducing hunger and strengthening food security (130). The policy and governance frameworks in which this is happening can provide strategic opportunities to mainstream agricultural biodiversity for diverse, healthier and more sustainable diets. Brazil has recently strategically targeted several of its policies to promote local and indigenous biodiversity for food and nutrition (131). Actions taken in Brazil include promoting diverse, healthy native foods in dietary guidelines; supporting production of food biodiversity through public procurement strategies (e.g. for foods in schools); and prioritizing food biodiversity in relevant national strategies/action plans and agriculture and nutrition policies (see Box 2.5).

BOX 2.5 – Brazil's policies that strengthen food and nutrition security through use of food biodiversity

Fome Zero (Zero Hunger) has been Brazil's foremost campaign against hunger and food insecurity since 2003. It takes a multisectoral approach, contributing to family farming, inclusive rural development and improved accessibility to food through various social protection options. Brazil has made progress in promoting agricultural biodiversity for improved nutrition by taking advantage of the horizontal and cross-sectoral governance mechanisms already in place under the *Fome Zero* umbrella and strategically targeting relevant public policies and instruments that can mainstream agricultural biodiversity. Public policies – such as the Food Acquisition Programme, National School Meals Programme, the National Food and Nutrition Policy, Minimum Price Guarantee Policy for Biodiversity Products and the National Plan for Agroecology and Organic Production – all provide suitable opportunities and entry points for potentially improving nutrition or livelihoods with links to native agricultural biodiversity.

For example, in 2009, the **National School Meals Programme** decreed that at least 30% of the food purchased through its programme must be bought directly from family farmers, who manage and conserve high levels of agricultural biodiversity. **The Food Acquisition Programme** also pays 30% more for organic and agroecological food from family farmers, thus encouraging local, diversified procurement (132).

The realization of improved diversification of food procurement and school feeding has been further enhanced by the 2016 endorsement of a new public policy, Ordinance No.163 **Brazilian Sociobiodiversity Native Food Species of Nutritional Value**, which for the first time officially defines and recognizes 64 nutritionally valuable species and provides incentives for these species to be better integrated into food procurement and other initiatives. Most of the species on the ordinance are nutrient-rich fruits. It is anticipated that the ordinance will contribute greatly to better understanding and dissemination of knowledge on these species and will ultimately enhance their promotion and sustainable use across a broad range of relevant public and private policies and related initiatives. In particular, the species on the ordinance will now be more attractive for family farmers not only to grow and conserve, but also to use and commercialize, since they now have greater recognition by public initiatives especially the Food Acquisition Programme, the National School Feeding Programme and the Minimum Price Guarantee Policy for Biodiversity Products.

The Brazilian **National Plan for Agroecology and Organic Production** (PLANAPO) involves numerous ministries and is focused on promoting and supporting organic and agroecological production of healthy food. It aims to achieve this through the conservation and use of agricultural biodiversity (7). The first phase (2013–2015) of PLANAPO is estimated to have benefited more than 60,000 families and 23,000 young farmers through the implementation of credit schemes, insurance provision and capacity building for agroecological food production. In PLANAPO's second phase (2016–2019) the aim is to have 1 million family farmers producing food using agroecological approaches. PLANAPO's second phase includes targets to determine the nutritional value of 70 native species and the publication of four books documenting the nutritional and other values of regional Brazilian flora.

The **National Council for Food and Nutrition Security** (CONSEA) is an advisory body to the Brazilian presidency, which facilitates the participation and coordination of 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 (133). A National Conference on Food and Nutrition Security (CNSAN) is held every four years to set guidelines and priorities for food and nutrition security actions to inform policymaking at CONSEA. The fifth CNSAN, in November 2015, incorporated biodiversity as one of the main aspects related to food and nutrition security.

Food Fair in Mongu (Barotse floodplain), Zambia, to raise awareness of how to prepare delicious recipes from locally available, traditional foods, many of which are nutrient dense. Zambia is home to rich biodiversity, with about 100 cultivated plant species, including cowpea, sorghum, Bambara groundnuts, beans, maize and 16 species of domesticated animals (mainly cattle and chicken), which can be used to improve diets and nutrition and address micronutrient deficiencies.
Credit: Bioversity International/E.Hermanowicz

School feeding programmes

The majority of countries around the world already provide school meals of one kind or another, feeding an estimated 368 million children daily and representing an annual investment of roughly US$75 billion (134). While there is growing recognition of the potential for schools to provide and promote the consumption of healthy, diversified foods by increasing the demand for local farm products, and supporting more efficient local food procurement and delivery systems, the actual integration of underutilized, nutrient-rich food biodiversity to date has been limited and therein lies an opportunity (135).

The *2016 Global Nutrition Report* (1) highlights that "schools provide a huge opportunity to reset norms about healthful diets and good nutrition practices" (p5). The same report provides guidance on realizing diverse diets and healthy eating environments in school settings as well as how school feeding can support agricultural development, such as through the reorienting of school feeding and public procurement in Brazil (1, panels 1.4, 6.2 and 6.6).

Homegrown school feeding programmes actively seek to procure food locally and provide opportunities to encourage sustainable and healthy sourcing while promoting short supply chains. 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 in Kenya (136). Underutilized minor millets incorporated in school feeding programmes have enhanced the nutritional status of school children in certain areas of Karnataka state, India (137). With the inclusion of minor millets in the Public Distribution System through the 2013 National Food Security Act (138), India has created an unprecedented opportunity to promote these highly nutritious and climate resilient crops for the benefit of millions of school children and the population at large.[iv] Greater efforts are needed though if this policy is to have major impact, as most states in the country lack a suitable implementation framework that would set adequate levels of subsidies for growers, procurement rules (including minimum price) and promote best agronomic and technological practices (i.e. production of good quality seed, reduction of drudgery in cultivation, harvest and post-harvest operations) (139).

Dietary guidelines

Ensuring that food-based dietary guidelines – which are largely absent in low-income countries and limited in lower and middle-income countries – guide policy decisions to reshape food systems is one of ten specific priorities for action recommended by the Global Panel on Agriculture and Food Systems for Nutrition (5). National dietary guidelines aligned to local food cultures and local biodiversity are an example of how to improve the sustainability of food systems while encouraging healthy eating. In a recent review of food-based dietary guidelines, four countries – Brazil, Germany, Qatar and Sweden – were singled out for progressive guidelines that encompass both concepts of sustainability and healthy eating (13). Some specific advice where food biodiversity can support sustainable healthy eating includes: eat seasonal and locally grown produce (Brazil), use fresh ingredients whenever possible (Germany) and chose high-fibre vegetables (Sweden).

Social and cultural attitudes

Supporting positive perceptions and norms regarding biodiverse diets, for example by celebrating food biodiversity at food fairs, such as the Alaçatı Herb Festival and the Urla Artichoke Festival in Turkey (140) and the Barotse food fair in Zambia, and collaborations with celebrity chefs, are another means to create an enabling environment with consumers. Many chefs are now popularizing neglected and underutilized biodiversity through restaurants and related food activities (141) and the potential to mainstream food biodiversity into initiatives such as Chefs for Development and Slow Food's Chefs' Alliance and Earth Markets is considerable. The substantial growth in 'culinary tourism' and the financial resources this attracts present unique opportunities for food biodiversity. Finally, the various beneficial facets of producing and consuming food biodiversity should be integrated into the curricula of schools, universities and other education institutions for broader action and uptake.

International policies and guidelines

Countries can use their National Biodiversity Strategy and Action Plans (NBSAPs), guided by an international obligation and framework through the Convention on Biological Diversity (CBD), to mainstream food biodiversity across multiple production sectors. However, to date this policy instrument has been poorly used for this purpose (142). Those countries who are signatories to the CBD are required to develop NBSAPs to mobilize resources and promote actions to achieve their commitments to the Strategic Plan and associated Aichi Biodiversity Targets. During the recent NBSAP revision process in Brazil, a broad policy consultation was carried out to reach collective agreement on the approach and definition of the new National Biodiversity Targets for 2011–2020. During the revision process the "limited appreciation of the use of biodiversity for food and nutrition" was identified as one of a number of causes for biodiversity loss in the country, resulting in the inclusion of nutrition-related objectives, targets and indicators (143).

The FAO Commission on Genetic Resources for Food and Agriculture, at its 15th session in 2015 formally adopted *Voluntary Guidelines for Mainstreaming Biodiversity into Policies, Programmes and National and Regional Plans of Action on Nutrition* (38). The guidelines support countries in the integration of food biodiversity into relevant policies and actions to help address malnutrition in all its forms, and to promote knowledge, conservation, development and use of varieties and breeds of plants and animals used as food, as well as wild, neglected and underutilized species contributing to health and nutrition.

Metrics to measure food biodiversity for healthy, diverse diets

Transformative change to sustainable food systems delivering healthy diets will require significant commitment by diverse stakeholders at a global level. Toward this end, indicators and metrics are needed which track progress towards broader nutrition outcomes such as reduced micronutrient malnutrition, rather than our current fixation on calorie adequacy (144). In addition, we need to better understand how the quality and diversity of production supports smallholder households in consuming healthy diets and diversifying income opportunities, while also ensuring affordable market-based choices for peri-urban and urban consumers. At present, the importance of agricultural biodiversity for healthy diets is not adequately measured or valued in prevailing metrics systems (3, 7). Beyond conventional measures of agricultural production and yield, such metrics systems need to integrate indicators that measure nutritional quality, nutritional diversity of food systems and diet diversity (143). This section focuses on metrics and proxies for: (1) consumption of food biodiversity, (2) food biodiversity in markets and (3) the enabling environment for enhanced use of food biodiversity.

Metrics and proxies for consumption of food biodiversity

Measuring the actual food biodiversity that people eat

One of the most accurate measures of dietary intake of individuals is the quantitative 24-hour recall method. Data collected using this method can be used to create several indicators that relate to intake of biodiverse foods (145). Metrics of individual dietary intake that collect information at species or subspecies level would measure in the most accurate way possible the contribution of food biodiversity to dietary intake and overall diet quality. These metrics include species richness in the diet or even intraspecies diversity consumed (146). Indicators not in widespread use, but that are currently being tested, include species diversity scores or richness of species by food group consumed. One drawback of methods that use a 24-hour recall period is that seasonal usage of food biodiversity in diets is not measured unless the data are collected over several distinct seasons throughout the year. A second drawback is that few countries routinely use this method for national-level data collection, therefore data availability is patchy and most often representative of subnational areas within a country. However, the Food and Agriculture Organization with the World Health Organization are piloting a platform called the Global Individual Food consumption data Tool (GIFT) which is intended to provide open access to individual level 24-hour recall data. Several indicators that could help link the role of food biodiversity to healthy diets have been proposed in the GIFT pilot phase, including:

- Main food sources of vitamin A in the diet
- Main food sources of iron in the diet
- Main food sources of zinc in the diet
- Intake in grams/day OR g/kg of body weight/day of healthy (fruits, vegetables, whole grains, nut/seeds) and unhealthy (processed meat, sugar-sweetened beverages) food items.

Measuring diet diversity by food groups

In the current absence of a tool for measuring actual food biodiversity in diets, diet diversity scores can be used as a proxy. Diet diversity scores are relatively simple, practical tools for assessing the micronutrient adequacy of the diet in low-resource settings and in situations in which more in-depth dietary assessment is not feasible (147). There are two internationally recognized and validated standardized diet diversity scores currently available and becoming more frequent in use: Minimum diet diversity (MDD) for children 6–23 months of age and minimum diet diversity of women 15–49 years of age (MDD-W). The definitions of these indicators are presented in Box 2.6. Data for children are being routinely collected by Demographic and Health Surveys (DHS).[v] Data for women are not routinely being collected at a nationally representative scale, however MDD-W is widely used in programmes including the United States' programme Feed the Future and Germany's One World No Hunger. With promotion and recognition of the need to collect more information on diets globally, the MDD-W could be an indicator of choice for informing policymakers at international and national level of dietary patterns for this vulnerable population group. In addition to looking at percent of population achieving MDD-W the percent of populations consuming individual food groups can be analyzed. This does not alter the data collection tool, but emphasizes the different ways that the data can be analyzed to provide a much more robust indication of the level of diversity of consumption across food groups.

The World Food Programme collects another composite indicator, the Food Consumption Score (FCS), which is considered more of a food security indicator. Data collected are representative of a household, rather than an individual. From the point of view of measuring food biodiversity, FCS has similar drawbacks to the two diet diversity scores described. The Food Frequency Questionnaire (FFQ) is another tool that is used to directly assess the dietary intake of individuals, and food biodiversity metrics could potentially be constructed from these FFQ data. However, similar to the 24-hour recall method, the food frequency questionnaire method is not routinely used on a widespread basis to collect information on dietary intake.

BOX 2.6 – Definitions of minimum diet diversity

Minimum diet diversity scores are based on recall of the previous 24-hour period,

Minimum diet diversity in children 6–23 months is defined as: *the proportion of infants and young children 6–23 months of age who consumed food items from at least four of the seven defined food groups the previous day or night.*

The seven food groups used to calculate the indicator are: (1) grains, roots and tubers; (2) legumes and nuts; (3) dairy products (milk, yoghurt, cheese); (4) flesh foods (meat, fish, poultry and liver/organ meats); (5) eggs; (6) vitamin A-rich fruits and vegetables; and (7) other fruits and vegetables.

Minimum diet diversity for women is defined as: *the proportion of women 15–49 years of age who consumed food items from at least five out of ten defined food groups the previous day or night.*

The ten food groups used to calculate the indicator are: (1) all starchy staple foods, (2) beans and peas, (3) nuts and seeds, (4) dairy, (5) flesh foods, (6) eggs, (7) vitamin A-rich dark green leafy vegetables, (8) other vitamin A-rich vegetables and fruits, (9) other vegetables, and (10) other fruits.

Source: (148, 149)

Measuring food biodiversity in the national or global food system indirectly

An indirect but comprehensive way to measure food diversity at national or global level is through use of the FAO statistical database (FAOSTAT). FAOSTAT collects information worldwide on agricultural production, imports and exports, and uses of production including food and animal feed. The information generated on food available for human consumption is calculated to per capita figures based on national level population and demographics. These data provide a proxy for national level consumption, but cannot supply a direct measurement of dietary intakes. This database can be used to construct novel measures of production and consumption diversity (150). Potential indicators that can be calculated using the FAOSTAT data for tracking consumption diversity include 'Shannon entropy diversity', using the diversity of food items produced and supplied; Nutritional Functional Attribute Diversity describing the diversity in nutritional composition of food items produced and supplied; and percent of dietary energy supply per capita from non-staples. Additional alternative indicators based on use of FAOSTAT that could relate to food biodiversity include g/capita of foods recommended in food-based dietary guidelines, such as fruits, vegetables, legumes, nuts and seeds.

Finally, open-access Living Standards Measurement Study data are housed at the World Bank and can be used to provide an indication of the amount of food biodiversity (only species or more aggregated level, e.g. oil) purchased for consumption by household members.

Proposed indicators to assess food biodiversity in consumption

Adequate measures of overall diet quality are needed that include more specificity both of within-food group consumption (e.g. not just a fruit was consumed, but which fruit species) as well as contributing factors to diet-related non-communicable disease and obesity, such as consumption of highly processed food and sugar-sweetened beverages (151–154). Additional important indicators of individual level diet quality are species richness in the diet and proportion of calories of ultra-processed food and sugar-sweetened beverages consumed (10, 25, 146).

Ideal indicators for measuring consumption of food biodiversity do not yet exist in a systematically tested and validated way. However, the GIFT database of FAO/WHO is a promising future platform where species specific indicators could be derived.

In the absence of a validated metric of food biodiversity and lacking a comprehensive, accessible database of 24-hour dietary intake or food frequency questionnaire data for most countries, minimum diet diversity for children 6–23 months of age and minimum diet diversity of women 15–49 years of age are the most widely used and openly accessible indicators of diet.

Metrics and proxies for food biodiversity in markets

Diverse stakeholders representing the public and private sector and civil society, both within and outside of agri-food value chains, manage different types of information – a good entry point for a joint metrics system that helps measure progress towards healthy diets and sustainable food systems from a market perspective.

Measuring food biodiversity in markets for sustainable food systems

As a point of departure, diversity of local markets and food outlets is an important indicator for estimating the availability of food biodiversity in the market. The presence of local markets in diverse environments (city centres, suburbs, peri-urban and rural areas), for example, is a good proxy for diet variety as, from both a producer and consumer perspective, better market access increases diet diversity through increased levels of purchased food diversity (107). At present, the quality and quantity of data on market diversity vary widely from country to country and from region to region. Additional data will need to be collected for given countries and regions, but probably on a case-by-case rather than a regular basis.

Similar to the indicators on consumption, metrics and proxies for food biodiversity purchased in markets tend to focus on food groups. The share of each category (grains, vegetables, fruits, meat/poultry/seafood, dairy, beans/eggs/nuts) as part of total consumption (in terms of item counts) has been proposed (154), with higher values of the generated consumption index indicating higher diversity. In addition to volume-based metrics, prices of different food species and varieties sold in the market indicate consumption trends and can be linked to the different degrees to which certain species and varieties contribute to healthy diets. Higher consumer prices signal increased difficulties for low-income groups to diversify their diet in terms of both the total counts and the balancing of the varieties consumed (see examples from China, 154). Rather than monitoring prices of numerous individual foods, the focus should be on principal foods that are representative of different food groups. This also accounts for the fact that price information is available at species rather than variety level.

Food choice trends can also be captured by monitoring import and export data of key food groups and highly processed foods that move through more formal market channels. Equally important, but less readily available, are data on post-harvest losses. While they are critical to understand efficiencies in agri-food value chains and the overall move to sustainable food systems, they are usually based on case studies rather than being collected on a regular basis.

Finally, a market lens for assessing the progress towards sustainable food systems means looking into the environmental performance of principal agri-food chains. This is an important indicator complementary to the quality of the foods offered. Data are available for principal food companies committed to reporting according to the *Guidelines for Sustainability Reporting* at company level, within the framework of the Global Reporting Initiative (155) as described by Hoekstra et al. (156).

Proposed indicators to assess availability, affordability, accessibility and acceptability of food biodiversity in markets

In the absence of existing metrics systems that routinely measure several of the above indicators at national level and subnational levels, we recommend a focus initially on the following indicators for which data are more readily available:

- Diversity of retail outlets – with data from national governments (e.g. National Statistics Institutes, Ministries of Economy)
- Prices of principal foods representative of different food groups – with data from national governments (e.g. National Statistics Institutes, Ministries of Agriculture) and regional organizations (e.g. Agrimonitor tool of the Inter-American Development Bank)
- Trends in the diversity of nutritious ingredients in the packaged food industry, with standardized and cross-comparable statistics including total market sizes, market share, distribution and industry trends – with data from Euromonitor International
- Import/export of key food groups and highly processed foods – with data from FAOSTAT and national governments (e.g. National Statistics Institutes)
- Environmental performance of principal agri-food companies – with data from the Global Reporting Initiative.

Metrics to assess enabling environments for using food biodiversity

As highlighted earlier there are a breadth of policies and other elements of an enabling environment which could be used in a scorecard for countries to assess how well agricultural biodiversity is being mainstreamed for healthier eating environments and improved nutrition. This is also an area of increasing global interest and action and there are already ongoing initiatives underway to foster healthy eating environments or promote 'nutrition-sensitivity' of policies and programmes into which food biodiversity mainstreaming can readily tap.

A starting point could be an assessment of a country's current policies and enabling environment context, targeting private and public policies, other relevant national instruments (e.g. National Biodiversity Strategies and Action Plans and national food-based dietary guidelines) and ongoing nutrition-sensitive programmes and actions (e.g. food procurement and school feeding), to identify those which support or provide incentives for mainstreaming food biodiversity. Such an approach is similar to a 'policy portfolio' review of the food and agriculture sector to determine the impact of the existing policy portfolio on food environments and diets as well as identifying where opportunities might lie for improving impact through a new policy or revision of existing policies (129), but which is specific to mainstreaming agricultural biodiversity.

Hand-in-hand with measuring the opportunities for mainstreaming biodiversity is the need for countries to reduce the impact of those prevailing policies and actions, including subsidies and incentives, which work against the promotion of healthy food and agricultural biodiversity including unhealthy food promotion and advertising.

Assessing policies and an enabling environment is important to support the use of food biodiversity in sustainable food systems for healthy, diverse diets. It does not, however, measure actual changes in levels of agricultural biodiversity, nor can it be linked directly to outcomes such as improved nutritional status.

A scorecard approach to relevant public and private policies and other instruments could quickly reveal whether those policies already in place promote or incentivize food biodiversity for improving healthy diets and nutrition, and may simply be a matter of assessing yes or no. Example questions might be:

- Does a country mainstream agricultural biodiversity to improve healthy diets and nutrition outcomes in its National Biodiversity Strategic Action Plan (NBSAP)?
- Does a country have a national multisectoral strategy and action plan for tackling nutrition or national dietary guidelines?
- Do current policies influencing food composition, labelling, marketing, pricing and provision consider agricultural biodiversity for improving healthy diets and nutrition outcomes?
- Does research on food composition and food consumption at national level use a sufficiently detailed description to identify genus, species, subspecies, variety/cultivar/breed, and local name?
- Are there policies in place which provide subsidies/ incentives for producing healthy agricultural biodiversity foods?
- Are there policies in place which support food biodiversity food choices in schools and other public settings?

Probably the most important and overarching of all of these questions is:

- Does a country have in place national food-based dietary guidelines which highlight the importance of food biodiversity not only for healthy diets and nutrition outcomes but also the many other multiple benefits including environmental sustainability and social equity?

Conclusions

Food biodiversity, or the diversity of plants, animals and other organisms used for food, covering the genetic resources within species, between species and provided by ecosystems, contributes to healthy and diverse diets in various ways. It reaches consumers through two principal pathways: (1) consumption via own production or gathering from the wild, and (2) purchase of wild or cultivated biodiversity. There is strong evidence of the importance of variation in nutrient content within and between species for addressing micronutrient deficiencies, as illustrated by the striking difference in nutrient content among different cultivars of the same species, and the superior nutrient content of several wild species when compared to domesticated types. From the perspective of the first pathway, production diversity is associated with improved diet diversity in most cases. Both on-farm and wild food biodiversity provide an important seasonal food and nutrition security buffer, particularly in the leaner months of agricultural cycles that affect rural populations, but also as a strategy to provide diversity in diets of both urban and rural populations all year round.

Women play a key role in both pathways, either as primary cultivators of food biodiversity that can diversify the household diet and as keepers of the traditional knowledge related to the wealth of plants, animals, insects and fungi that can be used as food, or as key actors making food choices when purchasing food in markets. Key factors influencing food choice are availability, accessibility, affordability and acceptability. Along with political-legal and institutional factors they make up the food environment that shapes consumer choice, particularly as populations urbanize, retail options expand to include supermarkets and fast food outlets, and convenience becomes ever more important. A particular challenge for the second pathway is to ensure healthy, diverse and affordable food options among low-income consumers who constitute the bulk of malnourished people, while offering attractive farm-gate prices to producers who supply these in a sustainable fashion. This will require multisector collaboration, involving stakeholders in agri-food value chains, service providers from outside of the chain, regulatory bodies and the media.

Public and private policies and programmes at the interface between agriculture and nutrition can help create an enabling environment for promoting healthy diets. With the appropriate regulations and incentives, they can have a profound influence on the types of food (fruits, vegetables, nuts, pulses) produced and can boost the consumption of healthy diets based on food biodiversity through public procurement programmes, such as school feeding and other social protection programmes.

Progress toward healthy diets as a critical element of sustainable food systems requires appropriate indicators and metrics systems for monitoring and learning. However, an important outcome of this review is to highlight that many of the indicators in current use are not well aligned with the measurement of food biodiversity. From a pure biodiversity lens for healthier diets, for example, reliable data for many fruits and vegetables – key elements of healthy diets – are not readily available at species, let alone subspecies, level. We therefore propose a pragmatic set of indicators that build on existing metrics and proxies to measure how food biodiversity contributes to diet diversity, and how market diversity and the enabling environment can boost these contributions. For example, FAO and national governments' statistics are a huge resource that can be used to understand trends in national food production and consumption. More granularity will need to come from additional data collection at national and company level. Towards this end, the Agrobiodiversity Index can be an important catalyst for researchers, policymakers and practitioners to better leverage the nutritional and productive potential of the food biodiversity existing on the planet.

Notes

[i] Vitamin A is fat soluble so, in order to fully utilize the vitamin A present in the foods, a small amount of fat needs to be added to the meal.

[ii] Bioversity International and FAO have developed guidance on the assessment of food biodiversity in dietary assessment surveys (12).

[iii] Five of the studies were included in both reviews. In the studies included in the reviews, on-farm diversity is most commonly measured as number of crop species grown (crop count). Some but not all studies include livestock. In both reviews, these farm-level indicators of production diversity are considered measures of agricultural biodiversity. Diet diversity scores of individuals or households were the most common nutrition indicator applied in the studies reviewed. Diet diversity was mostly defined as a count of the number of food groups consumed by a household or individual over a reference period, but in some studies a count of food items (rather than food groups) was measured. The number of food groups used to construct the diet diversity scores as well as the length of the reference period (previous 24 hours, previous 7 days) varied across the studies.

[iv] https://ccafs.cgiar.org/research/results/india-promotes-climate-resilience-through-its-food-security-bill#.WMGCqU0zXrc

[v] All DHS data are open access and can be obtained from http://dhsprogram.com/data/available-datasets.cfm.

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Rice terraces growing the improved Biramphul-3 variety of rice. This variety was developed together with farmers, using a participatory plant breeding methodology. Begnas Village, Kaski District, Nepal.
Credit: Bioversity International/J.Zucker