From Food and Human Diets to Nutrition, Health, and Disease

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Agrobiodiversity and Feeding the World

More of the Same Will Result in More of the Same

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Abstract

Food systems large and small around this planet are changing more quickly and more profoundly than ever before in human history. If the same processes and priorities continue, we can expect more of the same results: the last fifty years of a productionist paradigm have resulted in increased production of a small set of calorie-dense crops, increased calorie availability, and increased global homogeneity of diets, while environmental sustainability, human health, and equity issues remain unresolved. Food system sustainability is threatened by soil erosion, fertilizer pollution, water overuse, tropical forest degradation, climate change, and genetic uniformity in agricultural production. Meanwhile, access by all to healthy, diverse, and safe food choices is far from realized, and food-related noncommunicable diseases such as type 2 diabetes, obesity, and heart disease are now epidemics as the world increasingly partakes in a diet high in sugar, fat, and salt. There is reason for hope, as eaters on every continent are demanding healthier, more diverse, safer food. This chapter argues that agrobiodiversity will help to improve sustainability, equity, and nutrition outcomes in food systems. We briefly review the current evidence on the linkages between agrobiodiversity and sustainability, equity, and human health and nutrition, differentiating between linkages at different

Group photos (top left to bottom right) Anna Herforth, Timothy Johns, Hilary Creed-Kanashiro, Colin Khoury, Patrick Maundu, Bronwen Powell, Andrew Jones, Victoria Reyes-García, Timothy Lang, Hilary Creed-Kanashiro, Bronwen Powell, Anna Herforth, Timothy Johns, Patrick Maundu, Timothy Lang, Andrew Jones, Victoria Reyes-García, Timothy Johns, Anna Herforth, Patrick Maundu, Victoria Reyes-García

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geographical and temporal levels. We next identify research gaps in understanding the impact of agrobiodiversity on health. Because of the urgent need for action to create more sustainable, just, and nutritious food systems, we further propose tasks for the public sector as well as strategic alliances that support agrobiodiversity's contributions to sustainability, equity, and human nutrition.

Feeding the World: Battling Narratives

The productionist paradigm, which dominated mid- to late twentieth-century agricultural and food policy, has been successful in creating higher outputs of a few key crops and feeding more people. The model wobbled in the 1960s and early 1970s (during the first energy crisis) but was revamped and modernized by the continued Green Revolution with great effect (Chapter 6). Still, it was shown to be in a fragile state during the banking and oil crisis of 2007–2008 and was, yet again, polished and promoted by calls for more environmentally benign technical changes to tackle what analysts said would be the ultimate challenge: accommodating even more population growth and increasing dietary expectations as well, only this time in an era of climate change and the challenges of agriculture-related pollution and biodiversity loss. Consistent throughout the revamping of this model has been the perspective that problems can be resolved by producing more food (primarily staple grains, oils, sugar, and animal products) through ever more refined and sophisticated methods (Foley et al. 2011).

What can be predicted from proceeding down this familiar path?

First, more food. To clarify, more food of a certain type: more cereals, starchy root crops, meat and dairy, oilseeds, and sugar. Often emphasized in agricultural investments, these are the only foods tracked in the Food and Agriculture Organization of the United Nations' (FAO) food price index (FAO 2013). From a nutritional perspective, however, the emphasis on securing future consumption of these particular foods is increasingly puzzling. A diet comprised only of these foods would increase risks for negative long-term health outcomes. Sugars and fats, including saturated fats found largely in animal-source foods, are cited in a majority of dietary guidelines as components to limit because of their harmful relationship with health if eaten in excess (Herforth 2016). They are also the foods for which production and consumption have increased dramatically over the last fifty years (Khoury et al. 2014). Their increased consumption is a key driver of the nutrition transition and the global obesity epidemic (IFPRI 2016; Popkin 2004). Indeed, the projection of future food consumption is based to a large extent on trends in past food consumption—the same trends which brought with them social, health, and environmental resource impacts.

Second, in addition to more of the same kind of food, the dominant food narrative will bring more of the same kinds of malnutrition: obesity and

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diet-related noncommunicable diseases (e.g., cardiovascular disease, diabetes, cancer) will continue to increase, alongside persistent undernutrition and micronutrient deficiencies. This is a triple burden found in the same countries, communities, households, and even individuals within a life course (IFPRI 2016; Popkin 2004). Diet-related diseases have become a top risk factor in the global burden of disease (GBD Risk Factor Collaborators 2017). These dietary risks are due to the low consumption of fruits, vegetables, whole grain fiber, nuts, and seeds as well as high intake of sodium, processed meat, red meat, and sugars, including sugar-sweetened beverages. Diabetes, overweight, and obesity have risen in all regions and are projected to rise the fastest in Africa (e.g., IFPRI 2016).

Third, the current path supported through the dominant food narrative will produce more carbon emissions (Macdiarmid 2013) from the very production systems that are supposed to be designed as "climate smart" (Chapter 7). Myers (1997) and Hedenus et al. (2014) conclude that limiting global warming to a 2°C increase cannot be achieved without reductions in meat consumption, while others assert that we need to increase meat production to meet future food needs, particularly in low- and middle-income countries (McLeod 2011). A continued drive to produce more will also continue to exhaust natural resources (e.g., water, phosphorus), erode arable lands, and be a leading cause of the global decline in biodiversity, including pollinators, soil microorganisms, traditional farmer varieties and crop wild relatives, and other organisms that support the human agricultural endeavor (Bodirsky et al. 2014; Castañeda-Álvarez et al. 2016; Cordell et al. 2009; Foley et al. 2005, 2011; Matson and Vitousek 2006; Phalan et al. 2011; Rockström et al. 2009).

Fourth, the dominant food narrative's current production focus will continue to exacerbate wealth inequality, social and environmental injustices, and the power disparity between urban and rural areas as well as to devalue farmers and rural labor in general. Continuing the current production system will worsen the inequalities and injustices between urban and rural settings, with urban populations obtaining most of their food and energy from rural areas and returning their waste (Gracey and King 2009). The pressure to control the effects of industrial agricultural systems is lessening because the urban majority does not experience the environmental degradation and social injustices that affect rural populations (Coimbra et al. 2013). Moreover, the current agricultural production model places farmers and the farming profession at the bottom of the social ladder (Avila-Garcia 2016). This is intensified by the aging populations of farmers in high-income countries and increasing migration to cities in low- and middle-income ones (e.g., Martinez-Alier et al. 2016; Toledo et al. 2015).

These trajectories demonstrate that the status quo is unfit to improve the global nutrition situation substantially or to meet the sustainable development goals (SDGs) (UN 2015:15ff). Issues related to sustainability, nutrition, and health challenge current food systems and policy in most countries and

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institutions. The status quo is neither environmentally nor socially sustainable, rendering it economically unsustainable as well.

We envision that the following actions are necessary to support an alternative food narrative promoting sustainable, just, and nutritious food systems:

- Meet human nutritional needs and help to protect against noncommunicable diseases.
- Provide stable access to adequate food everywhere.
- Be resilient, that is, remain productive under changing and increasingly challenging environmental conditions.
- Conserve soil, water, and other natural resources; protect (agro)biodiversity; provide ecosystem services; and mitigate climate change.
- Minimize health risks and hazards, such as exposure to toxic chemicals and infectious diseases.
- Support social well-being and mental health.
- Provide culturally appropriate taste and variation and thus increase quality of life and demand for diverse species, varieties and breeds.
- Engender dignity, autonomy, and respect for all people.

Agrobiodiversity is one factor central to all of these desired goals. For the purpose of this chapter we refer to agrobiodiversity as "the variety and variability of animals, plants, and other organisms that are used directly or indirectly for food and agriculture, including crops, livestock, forestry and fisheries. It comprises the diversity of genetic resources (varieties, breeds) and species used for food, fodder, fiber, fuel, and pharmaceuticals. It also includes the diversity of nonharvested species that support production (soil microorganisms, predators, pollinators), and those in the wider environment that support agroecosystems (agricultural, pastoral, forest, and aquatic) as well as the diversity of the agroecosystems" (FAO 1999a). In a broad sense, agrobiodiversity is clearly essential to food and nutritional security and to human health (Friel et al. 2013; Frison et al. 2006; Graham et al. 2007; Johns and Sthapit 2004; Jones 2017; Negin et al. 2009; Powell et al. 2015). Yet this invaluable resource is threatened, including by the very agricultural systems that depend on it (Khoury et al. 2014). Alternative scenarios exist, however, where agrobiodiversity is able to flourish for the benefit of public health and the environment (Chapter 11), and such scenarios provide models for ways to transition toward more sustainable, just, and nutritious food systems. Adapting the words of President Bill Clinton (First Inaugural Address, January 20, 1993): "There is nothing wrong in [food systems] that cannot be fixed with what is right in [food systems]."

The "food shortage" paradigm (contained within the dominant food narrative) that arose in the twentieth century provided moral backing for productivity increases of a few major crops. Today, however, it has been asserted that the overarching food system problem is one of a nutritious food shortage (HLPE 2017; World Bank Group 2014). If food were equally distributed on the planet (which of course it is not), everyone would be able to satisfy or exceed their

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calorie needs, but it would still be impossible to fulfill their recommended dietary and nutritional needs (Herforth 2015). Specifically, not enough fruits, vegetables, and legumes are produced on the planet to meet the nutritional demand for those foods, while animal-based foods often are available only to the wealthy and not the undernourished who would most benefit from access to them. This nutritious food shortage stems from a focus on a narrow set of crops and livestock, which has effectively (socially, politically, and biologically) out-competed a wider range of foods that provide diverse nutritional attributes.

Offering a true alternative food narrative requires understanding agrobiodiversity as one of the keys to the world's current food system problem—the systemic mismatch of humans, biosphere, and food supply that has narrowed the diversity base of agriculture and produced the modern scourges of obesity and diabetes while failing to resolve hunger, food security, and micronutrient deficiency. Table 9.1 compares the alternative food narrative described above, in which agrobiodiversity plays a central role, to the current dominant food system paradigm.

Table 9.1 Moving toward a new agrobiodiversity-based paradigm for the food system.

	Current Food System Paradigm	New Food System Paradigm
Environmental considerations	Climate change	Agrobiodiversity conservation and many other environmental considerations in addition to climate change
Social considerations	Undernutrition and famine; poverty	Women's livelihoods and empowerment, smallholder farmers' livelihoods, just and decent livelihoods for workers along the food chain, nourishment for all
Economic considerations	Maximize profit from economies of scale, product homogenization for global trade	Potential for higher earnings from greater utilization of diverse, high-value crops
Primary solution	Produce more of the same	Increase diversity of production systems, food, and diets
Results	Continuation of current dietary trends Widening gap in access to staples relative to other diverse plant foods Increased or insufficiently decreased carbon emissions, accelerating climate change Continued increases in diet-related noncommunicable diseases	Increased access to a diet that matches dietary recommendations, healthier diets Improved food security Increased equity and justice in the food system Reduced carbon emissions Increased adaptive capacity to climate change Decreased incidence of diet-related noncommunicable diseases

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We argue that agrobiodiversity is an essential concept and actuality for the transition to a new food system paradigm. The ideas presented in this chapter are the outcome of one of the four groups in the week-long Ernst Strüngmann Forum, which discussed and evaluated the linkages between agrobiodiversity and sustainability, cultural equity, dignity, and viable livelihoods, and human health and nutrition for the purpose of identifying future research needs. We present here what is currently known about these linkages, and what needs to be better understood in the future. Because of the urgent need for action to create more sustainable, just, and nutritious food systems, we also propose tasks for the public sector and strategic alliances that support agrobiodiversity and its consequences (environmental sustainability, social equity and justice, and human health) as well as a research agenda.

What Do We Know? Current Evidence about the Impact of Agrobiodiversity on Diets and Health

Growing attention is being directed to the importance of agrobiodiversity for human health and nutrition at the global, landscape, community, farm, and household level. We have sought to summarize and evaluate current scientific knowledge applied in policy making and management as well as the perceptions, open questions, and controversies at each of these different levels. We highlight how the relationships between agrobiodiversity and human health and nutrition are shaped by geography, culture, policy, and power differentials.

Global Level

Over the past 50 years, evidence from national food supply data suggests that human diets across the world have become more diverse in terms of lower dependence on starchy staples and more food groups consumed; at the same time, they are more homogeneous in a "global standard" diet dominated by a relatively small number of major commodity crops (Khoury et al. 2014, 2016). These crops have substantially increased their share of the total food energy (calories), protein, fat, and food weight provided to the world's human population. The most prominent plant foods include wheat, rice, sugar, maize, soybean, and palm oil. Such globalization of food supplies is associated with mixed effects on food and nutrition security, including reduced undernutrition in some regions alongside diet-related diseases caused by overconsumption of macronutrients (Khoury et al. 2014). Although reasonably successful in providing sufficient calories to all but 700 million of the world's population, global food production does not supply everyone with the foods and nutrients aligned with dietary guidelines (Herforth 2015). The environmental "foodprint" of the simplified production model is also unsustainable (Tilman 1999; see also

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Chapter 11). Inadequate focus on production, distribution, and availability of affordable fruit, vegetables, nuts, and seeds clearly contributes to these gaps.

The increased global homogeneity of diets is accompanied by a corollary decline in the importance of local or regionally important crops. Concern with regard to the global decline in agrobiodiversity and in particular the loss of crops and livestock and their many traditional varieties and breeds has been raised for over a hundred years, at least since botanist N. I. Vavilov traveled the world in search of plants useful for cultivation in his Russian homeland (Vavilov 1926b). He noticed that diversity was disappearing in the cradles of agriculture—places where crops and livestock had been cultivated continuously for thousands of years (Khoury et al. 2016). The alarm was sounded even louder by agricultural scientists fifty years ago, during the Green Revolution, when farmers in some of the most diverse regions of the world partially displaced their many locally adapted wheat, rice, and other grain varieties with fewer, more uniform, higher-yielding, professionally bred varieties (van de Wouw et al. 2009, 2010). At the same time, smallholder farmers in many parts of the world, particularly in rainfed, traditional, and marginal settings, have continued to maintain diversity as an integral part of food systems (e.g., Brush 2004; Perales and Golicher 2014).

While there is a global, scientific consensus of concern regarding the rate of loss of agrobiodiversity over the past century, this has been difficult to quantify (cf. Mekbib 2008; Shewayrga et al. 2008). Most of the statistics on agrobiodiversity loss can be traced back to a handful of reports (FAO 2010b) and books (Fowler and Mooney 1990) that reference a few studies which have been challenged (Heald and Chapman 2009). Many estimates likely represent inflated, generalized statements about the global state of crop diversity loss, the most common being some variation of "75% of diversity in crops has been lost" (FAO 1999b). Quantification of erosion is additionally complicated by the lack of data and inconsistent methodology used historically to measure diversity. The best evidence assessed changes in genetic diversity within cereal crop varieties associated with the Green Revolution and showed a decrease in diversity when farmers first replaced traditional varieties with modern types, but a more complicated relationship subsequently (van de Wouw et al. 2009, 2010). Further studies here are certainly needed, including qualitative studies (Chapters 2 and 3). It is important to emphasize that although the scientific community may lack the tools or the drive to show definitive changes in agrobiodiversity, in many locales its loss is abundantly clear to farmers and scientists working with farmers. Qualitative work can show that many varieties have been lost within farmers' lifetimes, or are simply not accessible to the farmer any more when one or two preferred high-yielding varieties are promoted, wiping out dozens of varieties within a span of a few planting seasons or years.

At the global scale, agrobiodiversity is clearly necessary for basic food provisioning and for avoiding catastrophic crop failure. Reliable access to food

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staples is important to nutrition and societal stability. For these aims, genetic diversity is needed to underpin the production of major staple crops. Gene bank (*ex situ*) systems are essential to the conservation of this genetic diversity and to ensure its availability to plant breeders via formal seed systems, but they do not sufficiently conserve all agrobiodiversity, neither do they provide access to all producers in food systems nor permit the ongoing evolution of agrobiodiversity via interaction with pests, diseases, and climatic change. Other strategies, in particular *in situ* conservation, are complementary to large gene banks, providing ongoing evolution and access to diversity at the community level (Chapter 2).

Landscape and Community Level

The idea that agrobiodiversity at the landscape scale (Amend et al. 2008; van Oudenhoven et al. 2012) might impact diet quality aligns well with the concept of the "food environment" (Herforth and Ahmed 2015). If better access to nutritionally important foods within the food environment shapes dietary choice in urban food deserts (Ramirez et al. 2017), it should also shape dietary choice in rural areas (Powell et al. 2013). However, little is currently understood about the ways food environments impact dietary choice in low- and middle-income countries, especially in rural agricultural landscapes (Herforth and Ahmed 2015; Powell et al. 2013). Cultural mindsets influence which type of market, farm, or wild foods people consume (De Schutter 2011; Vadi 2011), but dietary choices seem to be very easily influenced by structural elements, such as social status and gender, urbanization and food industry marketing, and trade policies (Nelson and Chomitz 2011; Toledo et al. 2015). This has largely been the case in many low- and middle-income countries where changes in food cultures, and the profound effect that structural factors have exerted on dietary choices, have led to the nutrition transition associated with rising rates of obesity and diet-related chronic diseases (Popkin 2004).

Presumably diversity within the landscape and foodshed (Horst and Gaolach 2015) supports access to a diversity of affordable foods in markets. The role of agrobiodiversity in a community setting was well-illustrated by Stanner (1969) in his research on Kitui Kamba markets, *ndunyu*. Many districts are notoriously poor in crops which grow well in a neighboring district. Stanner notes that maize grows well in *Migwani* (a village) while *Mutitu* (a neighboring village) which is dryer produces good millet, but is too dry for maize. He notes that "the wider distribution of these [market] commodities to rectify local deficiencies is undoubtedly a primary function of the *ndunyu*." The *ndunyu* is therefore of the greatest use in equalizing such local productive variations and arbitrary climatic strokes.

Recent research has shown that diversity at the landscape scale can support better dietary quality through access to wild and agroforest foods, and

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reductions in seasonality of food availability (Powell et al. 2013). The importance of wild or forest foods from diverse agricultural landscapes seems to be highly site specific. A review of primary research papers that assessed the dietary contribution of wild foods showed high variation in the importance of wild foods for diets and nutrition among studies (Powell et al. 2015). In a number of sites, wild foods made up a significant portion of nutritionally important food groups, including vegetables (between 83% and 43% of vegetables in diets were from wild sources in studies from Tanzania and Vietnam, respectively) and meat and fish (between 88% in the Brazilian Amazon and 0% in a pastoral community in Kenya were from wild sources). The contribution that wild foods made to total energy intake was low in most studies: despite this, wild foods accounted for a large portion of micronutrients consumed at a number of sites (Powell et al. 2015). Similarly, a recent study (Rowland et al. 2016) that examined the dietary contributions of wild forest foods relative to agricultural foods to various food groups across 37 forest adjacent sites in 24 tropical countries found high variation across sites in the proportion of fruit, vegetables, and animal foods from the wild. Forests contributed an average of 14% of the total supply of fruits and vegetables (sites ranged between zero and 96%) and meat and fish (between zero and 92%). The reasons for variation among sites are currently poorly understood, but are likely linked to landscape diversity as well as agricultural practices, including agrobiodiversity management or candidate foods available in a complex, distinct ecosystem. Studies have shown that a shift from less intensive subsistence (swidden) agriculture to more intensive (sedentary) agriculture at both the household and the landscape scale is associated with less wild food use (Broegaard et al. 2017; Schlegel and Guthrie 1973).

One example of landscape-level diversity is the presence of forests or agroforests within the agricultural landscape. In the last five years there have been a number of papers showing a relationship between tree or forest cover at the landscape level and various indicators of diet quality (Ickowitz et al. 2014, 2016; Johnson et al. 2013; Powell 2012). For example, Ickowitz et al. (2014) used Demographic and Health Survey (DHS) data to show a positive relationship between tree cover and children's dietary diversity in 21 African countries. They also found that consumption of fruits and vegetables increased with tree cover up to a peak of 45% tree cover and then declined.

While these studies suggest that landscape-level diversity in agricultural systems may be associated with improved diet, the pathways between tree cover and diet remain a "black box" (Powell et al. 2015). Income is unlikely to explain the relationship: although forests and forest products may contribute to income that can support food security (Angelsen et al. 2014; Pimentel et al. 1997), communities that live close to forests are often poorer than those who live further away (Angelsen and Wunder 2003; Sunderlin et al. 2008). Other pathways are plausible:

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- Tree cover impacts diets through the mechanism of farming systems that include more trees (and are more agrobiodiverse), providing a greater diversity of cultivated and wild foods as well as foods that contribute to healthy diets, such as foods from swidden agriculture and agroforestry (Ickowitz et al. 2016).
- Trees (agroforests) produce food groups important for healthy diets, such as fruits and vegetables (Powell et al. 2013).
- Agricultural systems with more forests and biodiversity are better able to provide the ecosystem services needed for the production of nutritionally important foods including pollination (Eilers et al. 2011; Garibaldi et al. 2011) and microclimate variation.

Temporal Level

The fact that different varieties mature at different times can confer improved food security and resilience. Agrobiodiversity, like other types of diversity, is insurance for more vulnerable communities. This is especially true among communities that depend on small land holdings, rainfed agriculture, and small-scale irrigation. In dry environments, rainfall can be erratic. Similarly, water resources are limited in many small-scale irrigation systems. Within a species, some varieties or types are better at withstanding adverse weather such as drought than others. Therefore, a farmer growing several varieties of one crop stands a better chance that at least one or more varieties will be favored by the prevailing weather.

In the Andes, where there is extensive agrobiodiversity of native potatoes and other species, such as maize and beans as well as other tuber crops (oca, mashua, olluco), the different varieties and species stretch production across different times of the year. This gives continuity of supply and pushes back the vulnerabilities of seasonality, enhancing food security (Graham et al. 2007). Some potato and tuber crop varieties, for example, come to maturity within three months while others take longer—up to eight months (Moscoe et al. 2017; Rodríguez et al. 2016). Even without staggered planting, the supply of this staple is extended by diversity in maturation time. The varieties also have different storage and processing characteristics, with some fresh tubers storable up to three months while others can be stored for up to six months. Freeze-dried potatoes remain edible for several years (de Haan et al. 2009, 2012a). Potatoes' availability can thus extend year round. Indigenous Peoples in Peru recognize and know this function of agrobiodiversity. The naming of some varieties clearly suggests cultural recognition of earliness. The availability of Andean maize varieties ranges similarly from three to eight months, providing much needed resilience in response to rainfall and irrigation uncertainty among smallholder farmers that include Quechua Indigenous People (Zimmerer 2014).

Furthermore, agrobiodiversity can prolong the period of nutrient availability. In Kitui County of Kenya, for example, five varieties of mangoes

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may be found on one farm. The variety called Kakeke ripens from October to December; Kikamba (the traditional variety) from January to February; Dodo from February to March; and Boribo and Ngowe from March onward. Mangoes represent an important source of vitamins A and C, and in this case the traditional variety (Kikamba) would have provided nutrients for only two months, but the additional varieties extend the period to at least six months. Protracted availability is also seen in pigeon peas and cowpeas, two important legumes in Kitui. A diversity of wild fruits, each with its ripening period, can be viewed similarly (e.g., Kehlenbeck et al. 2013).

Farm and Household Level

Recent reviews indicate that household-scale agricultural biodiversity (i.e., crop species richness) is consistently associated with higher dietary diversity among farming households (Jones 2017; Powell et al. 2015). However, this association is small in most cases (i.e., four to ten additional crop species are needed to increase household dietary food group diversity by one food group). Furthermore, the association is not linear but rather an "inverse U" relationship such that the association between crop species richness and dietary diversity is higher among households with low crop species richness and lower among households with high crop species richness. It is unclear if differential access to markets influences these dynamics. In most contexts, the association between crop species richness and dietary diversity does not vary across farms of differing market orientation. While diversification of production may limit opportunities for specialization that could increase access to niche markets, greater diversification may also increase opportunities for farmers to spread risk and to introduce emerging cash crops into their production systems. Regardless of the market orientation of farms, most farming families still rely on markets for a large percentage of their food purchases. Therefore, maintenance of agrobiodiversity is important in supplying markets with diverse foods, and the diversity of food available in these markets is important for shaping the quality of farming households' diets. Yet, maintenance of on-farm crop species richness for subsistence consumption remains an important strategy for maintaining household diet diversity even among more market-oriented farming households (Chapter 10). Horticultural crops cultivated in homestead gardens may be especially important for preserving this "safety net" of diversity for home consumption.

Market Interventions

Although marketing channels have been implicated for the reduction of agrobiodiversity when they demand conformity, homogeneity, and specific shipping-friendly properties, markets can also provide a strong incentive for conservation of agrobiodiversity when underutilized crops are cultivated and sold. Several studies demonstrate efforts to support agrobiodiversity through

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markets (Chapter 15). The following case studies show how markets have been harnessed to support agrobiodiversity.

Andean Grains, Bolivia

Commercialization, value chain, and demand limitations very often stem from the stigma of *food-of-the-poor* that accompany traditional crops, including Andean grains. Consistent efforts by a project supported by the International Fund for Agricultural Development (IFAD) was undertaken to popularize the consumption of Andean grains in ways that would create a positive image of the Andean grain (Giuliani et al. 2012). The most successful intervention of this nature was the strategic partnership developed with the Bolivian private coffee shop chain "Alexander Coffee." This joint venture resulted from a collaboration between the PROINPA foundation, the Bolivian NGO "La Paz on foot," the Italian NGO UCODEP (today Oxfam-Italy), and Bioversity International. This alliance launched promotional campaigns for underutilized species. Customers of Alexander Coffee shops across Bolivia were exposed to the nutritional benefits of Andean grains through attractive leaflets, table tents, posters, and tasting of attractive and novel Andean grain-based modern food recipes. The snacks, biscuits, and other food items developed with the support of Alexander Coffee's chefs were a great success and are now very popular items in the network of this catering chain with spillover effects in other shops. At the same time, this initiative promoted the establishment of direct linkages between Alexander Coffee and poor farming communities from Lake Titicaca for the supply of grains (for a discussion on economic value chain approaches to agrobiodiversity use and conservation, see Chapter 15).

From Neglected to High-Value Vegetables: The Promotion of Traditional Vegetables in Kenya

In Kenya, vegetables are an important accompaniment for the main staple dish called *ugali* or *sima* (*nsima* in Zambia and Malawi). Green leafy vegetables are cheap and thus readily affordable to many people in rural, peri-urban, and urban areas (Chweya and Eyzaguirre 1999). Being accessible to low-income communities, they play a crucial role in food security and in improving the nutritional status of poor families. Despite these beneficial attributes, leafy vegetables have generally been neglected by both researchers and consumers as resources for consumption and as a source of income. Vegetable diversity especially for urban consumers had narrowed significantly since colonialism. Local vegetables were stigmatized as associated with poverty and the past. Cabbage, kale, and occasionally Swiss chard (locally known as spinach) were the modern vegetables of choice with the diversity of African leafy vegetables being notably threatened in the 1980s.

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From 1996 onward, a consortium of institutions led by the former International Plant Genetic Resources Institute (now Bioversity International) researched and promoted traditional vegetables in Kenya. The Traditional Food Plants database of the Kenya Resource Centre for Indigenous Knowledge (KENRIK) at the National Museums of Kenya registers 210 species of local traditional vegetables consumed by more than 55 ethnic groups in the country. Ninety percent of these varieties grow in the wild or appear spontaneously in cultivated lands where they are managed. With the help of farmers, scientists prioritized 24 species. The following decade saw about a dozen promoted as high-value traditional vegetables, changing the vegetable landscape in both formal and informal markets in Nairobi. Production, consumption, marketing, and market demand for African leafy vegetables increased over the ten years of the program. This transformation was due to concerted efforts, including selection of seeds with preferred characteristics, determination of nutritional and agronomic qualities, capacity building of community groups, development of local seed systems and market linkages, food fairs, and cooking demonstrations. Efforts were supported by media campaigns and even street demonstrations.

By 2006, the consumption of traditional vegetables in Kenya no longer carried the stigma it once had. The choice of vegetables to grow or purchase became much wider with increased opportunity to sell any local vegetable (Gotor and Irungu 2010; Moore and Raymond 2006). Farmers who grew African leafy vegetables and their children tended to eat a greater diversity of vegetables, with positive impacts on diet quality and nutrition (Herforth 2010).

Ecuador: The Importance of Flavor and Taste

Flavor and taste encompass the physical, chemical, and neurophysiological aspects of food, while taste can be further understood as a multimodal and multifaceted social concept which may include how people come to perceive, value, and identify with gastronomy and other sensorial encounters. Social movements that are centered on gastronomy and flavors have shifted the appeal for a transition to regenerative food production from agriculture to *food*. They have thereby created space for "those who eat" and opened up the doorway for a broader public to join the traditionally rural peoples' movements of agroecology and food sovereignty. In 2015, the *Colectivo Agroecológico* in Ecuador initiated a provocative campaign to recruit 250,000 families (5% of the population) for "responsible consumption" (Sherwood et al. 2017). This campaign aimed to capture about USD 650 million per year of the present-day financial resources invested in food in the country and use it for alternative purposes. Through a collapse of dichotomies between rural–urban, producer–consumer and poor–rich, the campaign has grown in both size and intensity. The experience generated through the campaign reveals how the sensations, associations, and entanglements of food and its taste can have social outcomes

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that range from new forms of producing, distributing, and preparing foods, to involvement in transnational initiatives such as civil society-based efforts to overcome violence in the Amazon and to address pandemic overweight and obesity. The campaign has united practitioners from different and sometimes competing ethnic, cultural, and social traditions around a common purpose and cause: food enjoyment. In the same vein, other research has shown that consumer taste preferences are strongly linked to sustainable cultivation practices that are based on agrobiodiversity (Ahmed et al. 2010), and that taste preferences seem to be the most relevant motivation for those who continue to consume wild food plants in rural areas of high-income countries (Serrasolses et al. 2016).

Power and Culture

Landscape- and species-level diversity have had much to do with cuisines and identity among individuals, communities, and cultures (Chapters 11–13). Three examples of the connection between food cultivation, culture, and power are presented here. The first is a story of how food norms and culture can shift based on the introduction of varieties that were originally introduced from a different place and culture. The second proposes the concept of "*dietary keystone species*" for species that are central to a particular food culture. The third story is about power and how cultivating one's own food and sovereignty over that process can be empowering, regardless of any other more normative or biological outcomes. We direct the reader to more comprehensive compilations of case studies on this theme for other examples of the intersection between food, culture, and power (e.g., Posey 1999a).

Sunflowers, Russia, and the Americas

Sunflower is one of the few native North American crops. It reached Europe early in the Columbian Exchange and was found in the 1500s in European botanical gardens (as an ornamental) (Putt 1997). Peter the Great may have had an influence in spreading its importance in Russia, as he was an advocate of botanical gardens. In the Orthodox Church, diets were quite constricted during Lent, forbidding the more "developed" life-forms and foods (animals, butter, fat, and even plant oils like olive). For these reasons, and because it was not on the prohibited list, sunflower became the preferred oil in the region, eventually becoming the dominant oil year-round. The oil crop expanded across Eastern Europe, where it is still very important today, as well as in the Mediterranean, where it is second in importance only to olive oil. In the 1930s, Eastern European Mennonites who resettled in the New World (Canada, United States, Argentina) brought sunflower varieties with them, instigating major industries present in these countries today. Argentina

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remains a major producer with the crop providing the most important oil in the diet.

Dietary Keystone Species

The concept of a "keystone species" in ecology refers to species that have a disproportionately large effect on their environment relative to their abundance (Paine 1995). In the ethnobotany literature, "cultural keystone species" are those central to the traditional livelihoods of a given cultural group (Garibaldi and Turner 2004) and are often foods. "Dietary keystone species" would perhaps comprise foods central or critical to a nourishing traditional diet. A keystone species, if it were to disappear, would cause loss of a whole repertoire of dishes containing an important suite of food taxa and a profound dietary shift. For example, central Mexico is the birthplace and center of the agrobiodiversity of maize. Mexican cuisines are built around maize, including countless recipes that call for particular racial complexes and varieties. For example, a kind of fish stew requires a specific variety of large-kernel maize; if that variety were unavailable, it is questionable whether the soup could still be prepared. If the maize variety were to disappear, the entire recipe, including the flavor and matrix of nutrients available in it, could be lost. Likewise, among the Mijikenda of coastal Kenya, women mix up to seven species of vegetables: there is typically a main one, while the others are called *kitsanganyo* meaning "for mixing" with the main one. The purpose of *kitsanganyo* species is to moderate the texture, taste, flavor, and even appearance of the main vegetable. Each of the *kitsanganyo* species plays a specific role (Maundu et al. 2011).

Urban Agriculture, Lima, Peru

A study on the outskirts of Lima exploring the role of urban agriculture on nutrition and food security showed no change in diet, but indicated the social and psychological benefits of producing one's own food, in addition to a material contribution (Prain and Dubbeling 2011). Families mentioned that having home production saved them money that they could spend on other foods or other necessities as well as serving as a safety net by "having food on hand." Women producers stated that while it was very important to buy food, it was equally important for them to have a space to plant their own vegetables. By sowing their own crops or rearing animals, the women felt they were caring for the environment as well as for their own families' health by eating fresh and uncontaminated foods. They also consider the physical activity in itself healthy and contributing to their sense of well-being and relaxation. In this sense they felt that urban agriculture enhanced their quality of life (Chapter 8).

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What Do We Need to Know? Research Gaps in Understanding the Impact of Agrobiodiversity on Health

Clear changes in crop-species level diversity, both in agricultural fields and in per capita national food supplies, have been documented over the past fifty years, but the impact of these on human health and nutrition remains to be fully explored (see also Chapter 11). Accordingly, variation in food diversity availability, access, and utilization must be examined throughout food environments. Factors for analysis include changes in agricultural research policies and innovations; international trade regulations; international food aid policy; multinational, national, and local food companies' product penetration; markets, particularly supermarkets; demographics, particularly urbanization; and economic development, with particular emphasis on increased consumer purchasing power in many regions globally. Key elements of the analysis are cultural norms and changing dietary expectations, including increased demand for animal products, high fat, sugar and salt foods, and other "Western" foods; impacting these trends are celebrity chefs, organic agriculture products, health food industry products, and renewed emphasis on locally produced and traditional foods. Particular attention should be paid to the impact of agrobiodiversity interventions with the potential to resolve undernourishment and improve diet quality.

While strongly advocating agrobiodiversity's importance to nutrition and health as the central impetus for this paper, we consider here the state of the evidence and key gaps organized around the functions food systems should provide. These functions of agrobiodiversity include potential for improving nutrition and diets; for food security and resilience; for protection of health against risks and hazards; and for protection of dignity, autonomy, and quality of life. Inconsistencies and deficiencies in methodology or the ancillary nature of relevant research to date calls for a more systematic approach to refining and validating methods for directly assessing agrobiodiversity as it informs nutrition and health questions. Such approaches will necessarily merge quantitative and qualitative information, and can cut across both the natural and social sciences.

Potential for Improving Nutrition and Diets

While the link between excessive consumption of carbohydrates, protein, and fat in diets and noncommunicable diseases is well established, how changes in agrobiodiversity at the plant and animal species level have contributed to increased consumption of macronutrients is inadequately understood. The often high micronutrient content of underutilized species is also well known, but benefits of biodiversity with regard to major micronutrient deficiencies (vitamin A, iron, iodine, zinc) are not well elucidated. Furthermore, almost nothing is known about the impact of differences at the level of crop variety and

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animal breed diversity on human health at the global scale, and even less about the impact of simplification on both intestinal and oral microorganism diversity associated with dietary change (Obregon-Tito et al. 2015; Sonnenburg and Backhed 2016). Research oriented toward the identification of dietary keystone species for fulfilling micronutrient requirements, preventing noncommunicable diseases, and maintaining healthy microflora populations within the human body, while also supporting the social and cultural importance of diet, would be novel and welcome.

Data from various, mostly circumstantial sources support contributions of agrobiodiversity to positive nutrition outcomes and demonstrate how the protection of wild and cultivated diversity prevents undernutrition or noncommunicable diseases on a case-by-case basis. Nonetheless, more systematic evidence is needed to fully define these relationships or to predict how and when agrobiodiversity can be utilized for better health outcomes. Investigations from the several perspectives already discussed in this paper can continue to strengthen understanding of the relationships between agrobiodiversity and nutrition outcomes within different contexts ranging from populations adhering to more traditional patterns of resource use and exchange to those fully integrated into modern production and market economies. More research is needed to better delineate the contextual relationships and pathways responsible for the importance of wild foods for human diets and nutrition (Powell et al. 2015; Rowland et al. 2016).

As food systems are increasingly global and market oriented for a majority of the population, traditional foods will be increasingly accessed through markets. Some underutilized crops have become market commodities of regional or global distribution (e.g., quinoa, açaí, finger millet), sometimes marketed as "superfoods." From a health perspective, agrobiodiversity's contribution in such systems needs to be examined in relation to noncommunicable diseases. Do production and consumption of more diverse plants reduce noncommunicable diseases? Although evidence exists that more diverse plant foods aid risk prevention, research that establishes thresholds of minimum diversity, or proposes optimal diversity levels to reduce risk, will be useful.

Community-level foodshed diversity is an important scale yet to be more adequately understood as socioeconomic realities shift (Horst and Gaolach 2015). As an ever-greater proportion of farming families interact with urban environments, purchase some food in markets, and earn at least part of their household income off farm, research into the availability of and access to agrobiodiversity by communities through different mechanisms is warranted. While urban food deserts (Ramirez et al. 2017) are characterized by issues of availability and access, questions arise as to whether improving proximity to fruits and vegetables necessarily improves diets and nutrition. Equally, rural food deserts characterized by monotonous diets on farms where foods are grown predominantly for often distant markets deserve attention.

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Research that is defined by contemporary case studies and observational data has distinct limitations. Importantly, the few studies that have examined the association between household-scale crop species richness and dietary diversity among farming households have used many different approaches and indicators to assess the relationship, and all of the studies have relied on cross-sectional analyses (Chapter 10). Such analyses do not capture any potential longer-term nutritional benefits of agricultural biodiversity and also preclude the drawing of causal inferences to understand the relationship. Furthermore, changes in agricultural biodiversity may have impacts on dietary diversity and quality over longer time periods, or on populations outside of the producing families themselves. Therefore, methodological approaches applied to date to examine these dynamics may misalign with those needed to properly assess the potential impact of agricultural biodiversity on diet outcomes. Impact on diet and nutrition can be observable, albeit often small, but the more critical question could be related to loss of cultivated and wild species and varietal diversity from a whole food system. What effect would this have at the community level and beyond? Relevant prospective research requires continued compilation of empirical evidence, but also extension into modeling of system transformations.

Which policies and interventions support access to diverse food resources and the ability to maintain agrobiodiversity within production systems? Undoubtedly, different messages and policy applications are needed for different regions and social groups. What is appropriate and what works are themselves issues which urgently need to be resolved.

While in mainstream North America food culture is being reinvented, in many other regions such as Southeast Asia, East Africa, or the Mediterranean, food culture has never been lost (Johns and Sthapit 2004). Maintenance of biodiverse traditional food cultures provides a powerful tool for moving forward. Under what conditions do farmers stop or continue to eat their local and traditional foods when they enter markets? What are their economic, nutritional, and social vulnerabilities of engaging in specialized production systems (Johns et al. 2013)? Intermediation in markets is an essential aspect of policy-guided research focused on producers, consumers, and supply chain.

Potential for Food Security and Resilience

Population growth, coupled with the virtuous objective of raising living and health standards of the billions living in poverty, challenges sustainable food security in unprecedented ways, and agrobiodiversity's role in this context requires examination.

The specialization of farmers linked to markets may come at the expense of the resilience that agrobiodiversity offers, which can be examined as a determinant of a long-term livelihood strategy. How and where agrobiodiversity

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is important for specific groups, including women and children, needs better understanding. In places where people rely on agrobiodiversity for their subsistence and well-being, microstudies focused on mechanisms, whereby agrobiodiversity brings benefit, are important because that is often where interventions are targeted. Research focused on issues such as the seasonal importance of biodiversity to health and nutrition or understanding of how dietary keystone species, landscape, ecology, and sociocultural factors affect the relationship will continue to draw on comparative case studies from which generalizable patterns and insight emerge. Undernutrition remains a primary focus for such research.

Food security in the twenty-first century assumes a requisite response to climate change. Agrobiodiversity, as it comprises variation in crop microadaptation to variable temporal and spatial conditions in temperature, moisture, and other characteristics that have been exploited for millennia by farmers, offers a key resource. The resource capacity of agrobiodiversity in response to climate change (Chapter 7) is also linked to local and global mediation of future change (Brondizio and Moran 2008) that has potential social and gender dimensions (Bhattarai et al. 2015).

The role of formal and informal seed systems in mediating the connection between food security and agrobiodiversity needs better documentation (Mucioki et al. 2016). Similarly worthy of fuller examination is in-field diversity: Why is it important and to whom? Modern plant breeders might assert that spatial diversity of traditional systems has been effectively replaced by temporal diversity of modern systems (i.e., varieties partially replaced or renewed every few years). Indeed, there have rarely been widespread full crop failures based on this model over fifty years. However, power relationships come into play in the dissemination of improved varieties and their adoption, with diminishment of the role of agrobiodiversity in smallholder communities for market opportunities, seasonal home consumption, and social function (Chapters 8 and 13).

Potential for Protecting Health and Minimizing Health Risks and Hazards

Beyond direct, consumption-related impacts on diet and nutrition or on food production, potential pathways that link agrobiodiversity and health include reduction in the use of external inputs with detrimental effects on the quality of air, water, or soil (Chapter 11). Landscape diversity, structure, and management is related to vector- and foodborne disease transmission as well as use (and misuse) of agricultural chemicals (Bianchi et al. 2013; WHO/CBD 2015). Agrobiodiversity's role in minimizing exposure to pesticides and other agrochemicals can be further supported. Likewise, documentation of the ecology and environmental determinants of human disease in relationship to

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agricultural systems as evidenced by the examples cited above extends understanding of the role of agrobiodiversity.

Although the World Health Organization (WHO) includes mental health as an essential aspect in the definition of health, related research exploring links with the natural environment is lacking. Some potential pathways between agrobiodiversity and mental health could relate to access (or lack of access) to both sufficient food and food that is considered culturally adequate, or to pertinence to social networks which provide access to resources (e.g., seeds, information), social influence (e.g., spread of nutrition related behaviors), social engagement, the provision of social support (both perceived and actual), and the enjoyment of life through reduction of monotony (further discussed in Chapter 11).

Potential for the Protection of Dignity, Autonomy, and Quality of Life

While culture's potency as a mediator of human behavior has been recognized above in relation to the market link of agrobiodiversity and nutrition, food culture can be examined directly as a desirable outcome. What is the effect of agrobiodiversity loss on food culture and dietary keystone species? Conversely, it is important to understand food culture as a driver of conservation. Agrobiodiversity can be distinguished in relation to sensory qualities (organoleptic); anthropological research might further examine aspects of food enjoyment with both intrinsic and economic value (Ahmed et al. 2010).

Dignity, autonomy, and respect for all people define a principle rather than strictly a research topic, but this can be examined in relation to policy and decision making and self-reflectively as an influence on research agendas. The need for studying relationships and outcomes between agrobiodiversity and human health beyond nutritional indicators (e.g., food taste, cultural foods, cuisine, preparations, gender) calls for a more integral methodological approach. Such an approach will be developed not by going to the field with refined research tools to collect data on additional variables, but by building community-inclusive research agendas and developing trustful relations with communities. In this sense, communities should be addressed as full participants in the identification of local foods, varieties, and preparations of traditional, historical, and current relevance. Communities need to participate in finding workable solutions to problems emerging from the relationship between agrobiodiversity, food, and health. An example of a guide to research protocols is "Documenting traditional food systems of Indigenous Peoples: international case studies guidelines for procedures" by the Centre for Indigenous Peoples Nutrition and Environment (CINE) (Kuhnlein et al. 2006). In research involving Indigenous traditional knowledge and practices associated with the collective use of plants, animals, and insects, the participatory process should be recognized and attributed (cf. WHO 2003).

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Advocacy Gaps and Opportunities

Perhaps larger than research gaps are discrepancies in awareness and advocacy about the problem of declining agrobiodiversity and its potential for positive impacts on nutrition. At this Ernst Strüngmann Forum, we discussed and debated why the international community is not more engaged in agrobiodiversity as a central issue of our time. We believe that gaps in scientific evidence do not fully explain this lack of engagement. Rather, the lack of a coherent and compelling story, and the failure of scientists to communicate it, is a larger gap. There is a need to make the multiple stories clearer to a wide audience. What are the stories of agrobiodiversity in a world of over-, mal-, and under-consumption? The narrative of continued use by producers and consumers and the embeddedness of agrobiodiversity in society is less visible compared to the "doomsday" and "gene banks" story line.

The current international policy agenda on food and environment is dominated by climate change. It has taken 30–40 years of hard work and consistent, coherent evidence to achieve top-level policy engagement on critical global issues, including obesity and climate change. The international commitment to those topics is now manifest in the 2014 United Nations (UN) statement on noncommunicable diseases and the 2015 Paris Climate Change Accord (now ratified by over 55% of governments).

The lesson is that one needs a combination of good evidence, clear simple messages, and good organization to engage the policy agenda. The role of the Intergovernmental Panel on Climate Change (IPCC) is exemplary, but it has been enormously helped by the huge sociopolitical infrastructure of the NGO community, which has been active, noisy, and persistent on climate change. This mix of "inner circle" of respectable science and "outer circle" of nimble, noisy, active civil society is essential. One targets decision makers and formal institutions; the other does the same but by harnessing public attention. On obesity within health and food agendas, input comes from more "voices" and organizations—a good mix of inner and outer circles—and the message has been consistent, despite there being no one IPCC equivalent.

Environmental science offers many more policy challenges than just those posed by CO_2. Biodiversity and agrobiodiversity compete for policy attention with soil, water, land use, air, and the general concern about food supply in a time of climate change (see, however, African and other regional assessments of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services; IPBES 2018). The food system as a whole is widely agreed to be in stress (Gladek et al. 2016; GLOPAN 2016). However, concerns over biodiversity and agrobiodiversity do not rise as high as climate change, notwithstanding the reality that a major consequence of global warming for humanity is ultimately the loss of biodiversity (Rockström et al. 2009).

We recommend a proper review and advancement of the most effective strategy for enhancing the profile and importance of agrobiodiversity for

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nutrition and health. This should consider different options, different scales (global to local), and the role of different policy actors, including governments, companies, consumers, scientists, and civil society.

Meanwhile, one option is to attach agrobiodiversity more clearly to specific immediate threats. What does it have to offer to climate change adaptation or noncommunicable diseases? Are there any links? It always helps to get an issue onto the policy agenda if protecting and enhancing it can help resolve other problems for society and the planet. In short, agrobiodiversity needs to build the right mix of problem, solution, organization, and message to ensure greater attention at the policy level.

Accountability to Existing Commitments

There is a need to enforce and act on existing, signed international policies (Chapter 14). The following policies and initiatives are the most significant with regard to agrobiodiversity conservation, sustainable use, and human health:

- The Convention on Biological Diversity (CBD) requires parties to develop National Biodiversity Strategies and Action Plans (UN 1993). Agrobiodiversity is an integral part of both the Aichi Biodiversity Targets (Target 13) and the Global Strategy for Plant Conservation (Target 9). The Global Environmental Facility has supported various related initiatives, for example, the UNEP/FAO implemented the multicountry Bioversity for Food and Nutrition project.
- The International Treaty on Plant Genetic Resources for Food and Agriculture, in alignment with the CBD, outlines specific responsibilities with regard to plant agrobiodiversity (FAO 2009).
- Initiatives such as the CBD's Cross-Cutting Initiative on Biodiversity for Food and Nutrition, which was adopted at the 8th Conference of the Parties (COP8) under the Millennium Development Goals. The updated SDGs strongly consider agrobiodiversity conservation (Goal 2.5), environmental sustainability (Goals 7, 11, 12, 13, 14 and 15), and the need for improved human health (Goals 2 and 3).
- The World Health Organization, through initiatives such as the recent joint report "Connecting Global Priorities: Biodiversity and Human Health: A State of Knowledge Review" (WHO/CBD 2015). Among the thematic areas featured in the report are (a) agricultural biodiversity, food security, and human health and (b) biodiversity and nutrition.

Linking Agrobiodiversity to Related Agendas

While agrobiodiversity features prominently in some international agreements such as the CBD or the International Treaty on Plant Genetic Resources for Food and Agriculture, this is much less the case in relation to health policy

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decisions (see COP 12 Decision XII/21: Biodiversity and human health). The following examples show linkages between agrobiodiversity and identifiable global agendas of relevance to food systems and nutrition.

Food Security Agenda

Simply put, food security entails consistent access to diverse food to meet nutritional needs, as has been agreed to by all signatory nations for over twenty years (FAO 1996). Greater agrobiodiversity is undeniably necessary at the species level to make food security a possibility for all. At the varietal level, evidence needs to be astutely portrayed so that it becomes clear in what situations, and for whom, varietal diversity contributes to year-round food security through reduced seasonality and enhanced resilience.

Climate Change Agenda

Agrobiodiversity offers adaptation potential. For example, different native potatoes can be grown at different altitudes in the high Andes according to the climate, thus handily providing climate change adaptation. Also, complex knowledge systems are associated with the adaptive capacity of agrobiodiversity and are at risk of loss (Chapter 7).

Nutrition-Sensitive Agriculture

Agrobiodiverity is at the intersection between nutrition, agriculture, and environment because it offers a means toward nutrient adequacy, reduced seasonality, gender equity, and resilience. To some extent it is already embedded in the nutrition-sensitive agriculture conversation. FAO (2015:5) states that "diversified production systems are important to vulnerable producers to enable resilience to climate and price shocks, more diverse food consumption, reduction of seasonal food and income fluctuations, and greater and more gender-equitable income generation." FAO recommends interventions and policies that facilitate diversification and increase incentives for availability, access, and consumption through environmentally sustainable production as well as the trade and distribution of nutrient dense and safe crops and animal-source foods (e.g., horticulture crops, legumes, nuts, seeds, small-scale livestock, and fish—foods that are relatively unavailable and expensive, but nutrient-rich and vastly underutilized as sources of both food and income). Thus nutrition-sensitive agriculture assumes a coherent nutrition and ecosystem focus. The Scaling Up Nutrition (SUN) Movement Strategy and Roadmap (2016–2020) identifies agriculture and food systems as essential in making diverse, nutritious food more accessible to everyone, and supporting small farms as a source of income for women and families.

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Health and Nutrition Agenda

The UN Decade of Action on Nutrition (2016–2025), led by the FAO and WHO, embraces the current policy consensus that eating a variety of foods, including fruits and vegetables, is important for health. Abundant diversity of plant foods is one of the common characteristics of international and national dietary guidelines and epidemiologic research that protect against noncommunicable diseases (Herforth 2016). Researchers have yet to illustrate clear linkages between agrobiodiversity and people's access to a diversity of plant foods to protect health.

Sustainable Development Goals

While SDGs as a broad agenda indicate better food systems for sustainable diets, progress toward improved diets demands specific strategies and greater accountability. Despite the importance of health in 70 of the SDG targets related to food, none are tied to indicators that measure dietary intake. FAO and Bioversity International have articulated a concept of sustainable diets that directly links agrobiodiversity and nutrition (Burlingame and Dernini 2010). Although the discourse on sustainable diets and associated research has accelerated the emphasis on diversity for food and nutrient adequacy and resilience (Fischer and Garnett 2016; Gustafson et al. 2016; Jones et al. 2016), it has yet to realize the impact needed. Agrobiodiversity needs to be more effectively understood as integral to SDG 2, 3, and 5 at least. Goal 2 calls for food security, improved nutrition and sustainable agriculture. Goal 3 (UN 2015:18) calls for healthy lives and the promotion of well-being for all people at all ages. Goal 5, which strives to achieve gender equality and empower all women and girls (UN 2015:18), converges with nutrition and health priorities as underlined in the SUN Movement Strategy and Roadmap. Policies that are gender sensitive are more likely to value underutilized species and other components of agrobiodiversity that are typically grown and harvested by women (cf. Bhattarai et al. 2015; Johns et al. 2013).

Biodiversity Conservation Movements

The closest ally for agrobiodiversity may naturally be the conservation community. The World Wildlife Fund's "Metabolic Report" says food systems are essential for conservation (Gladek et al. 2016). But this rationale is often used as an argument to simplify and intensify systems ("Growing more intensively to spare"). How can it be reshaped to protect and support agrobiodiversity? A major shift in philosophy over twenty years has led to the understanding that conservation in diverse regions cannot succeed without the approval, buy-in, and participation of diverse local cultures. Perhaps it is not so different in the

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case of agrobiodiversity: conservation of agrobiodiversity needs both people and places to flourish. It cannot only exist in seed banks.

Where Next? (Conclusions)

Agrobiodiversity is an essential part of both the storyline and the mechanism for solving the world food problem. It underlies a shift in paradigm from merely a Green Revolution-era “food shortage” to an updated realization of a “nutritious food shortage”—which is a reflection of production systems that are lacking in diversity, sustainability, and equity with visible consequences on nutrition and health. The recent regain in food system thinking and practice reflects the more holistic take now being adopted by donors and policy makers when balancing nutrition security and the socioeconomic and environmental imprint of agriculture on people and planet. There are roles for the support and revalorization of agrobiodiversity at every level.

At the global level, the UN approved the SDGs in 2015 and the Paris Climate Change Accord, as well as updated biodiversity targets via the CBD, and more member countries have signed onto the International Treaty on Plant Genetic Resources for Food and Agriculture. In 2016, Habitat III addressed issues of the urbanized world (UN 2017a). These intergovernmental commitments and aspirations need to be translated into concrete, precise, and coherent actions at the local, regional, and national levels. Although nutrition is implicit in many of the SDGs and targets, precise actions are often lacking. Agrobiodiversity has much to offer. We want to see all member states create new SDG-informed commitments at their national and local levels. New public engagement is essential. Eating differently to protect and enhance biodiversity requires consumers and the food industry to change. More use of existing diversity, breeding, production, and trade, particularly in fruits and vegetables, is needed for building diversity in the field, not just in parks or forest edges.

Global trade policies and agreements have profound diet-related consequences (Friel et al. 2013). Since they impact access to healthy and unhealthy foods through global and local supply chains, they need to be more responsive to ensuring the benefits of agrobiodiversity for desirable health outcomes.

Civil society organizations worldwide are aware of the importance of biodiversity and some see agrobiodiversity as worthy of support. We urge them to give higher priority to the following:

- Support farm and food systems which do not “mine” the earth.
- Restrict herbicide and agrichemical use.
- Reinvigorate skills sharing and training to farm well by building on local knowledge.
- Link agrobiodiversity to youth engagement, education, and revalued local identity.

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- Conduct annual “state of nature” farm and food reviews to hold governments to account.

Supporters of “nutrition-sensitive” agriculture should consider how to be both nutrition and ecosystem sensitive. A new generation of extension and advisory services needs to halt the degradation of ecosystems and enhance their protection. Gene banks have their place, but agrobiodiversity *in situ* is a useful means for retaining a pool of genetic diversity in the field, spread across regions and growers. Hundreds of millions of people are already caretaking biodiversity through their livelihoods, even if they do not conceive of themselves in that way.

The most sensitive issue of all concerns the role of the public. Consumers eat the environment. The global rise in meat and dairy consumption is widely agreed to be a major driver of ecosystem threats, notably of climate change. Different messages are needed for different regions and social groups. Little advantage rests in asking consumers in low-income societies to eat less when they desperately need to have access to more and better diets. Yet, there is a value to promulgating the message to eat less but more sustainably to high-income society consumers. What is appropriate, and what works where, are themselves issues which urgently need to be resolved.

Our final appeal is to fellow scientists. First, agrobiodiversity must be more consistently and openly supported. The complex relationship of biodiversity, food, and nutritional health requires us to speak out coherently and with united and clear voices. Scientists and researchers often relish the incompleteness of their tasks: there are always new questions to ask, new avenues and connections to explore, new data and insights to absorb, new pathways to map. The connections between biodiversity and health are no exception to this, nor is the role of agriculture and food lacking in fascinating, complex issues to explore. The debate, however, about what agrobiodiversity has to offer for improving public health and nutrition in an era where diet is the factor with greatest impact on noncommunicable diseases—the most significant but not the only source of twenty-first century ill-health—is of importance not just to scientific journals but to everyone. The real world of farms, fields, and food systems has entered a new era, the Anthropocene, in which human activity is both driving and being shaped by the consequences of our collective actions. These are well-known and documented by science—climate change, ecosystems stress, demographic change, the nutrition transition and more. Scientists in all our organizations must come together to give clear, coherent, evidence-based advice and advocacy. We cannot expect public opinion and behavior to adapt to the Anthropocene if we add to the policy and cultural cacophony, or worse, keep silent waiting for yet more research to answer our questions. Despite the need for more and better knowledge, we already know enough to speak up and out for the value of agrobiodiversity for human health, joy, and indeed, survival.

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