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Agricultural biodiversity and food system sustainability

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Transformation

KEY MESSAGES:

- → Food systems need to be reformed so that they nourish people while nurturing the environment.
- → Agricultural biodiversity is a source of nutritious foods which are culturally acceptable and often adapted to local and low-input agricultural systems. It is also a source of important traits for breeding resilient, nutritious crops and animal breeds.
- → Agricultural biodiversity is already a key component of farming systems and breeding systems worldwide.
- → The Agrobiodiversity Index will help policymakers and the private sector to assess dimensions of agricultural biodiversity to guide interventions and investments for sustainable food systems.

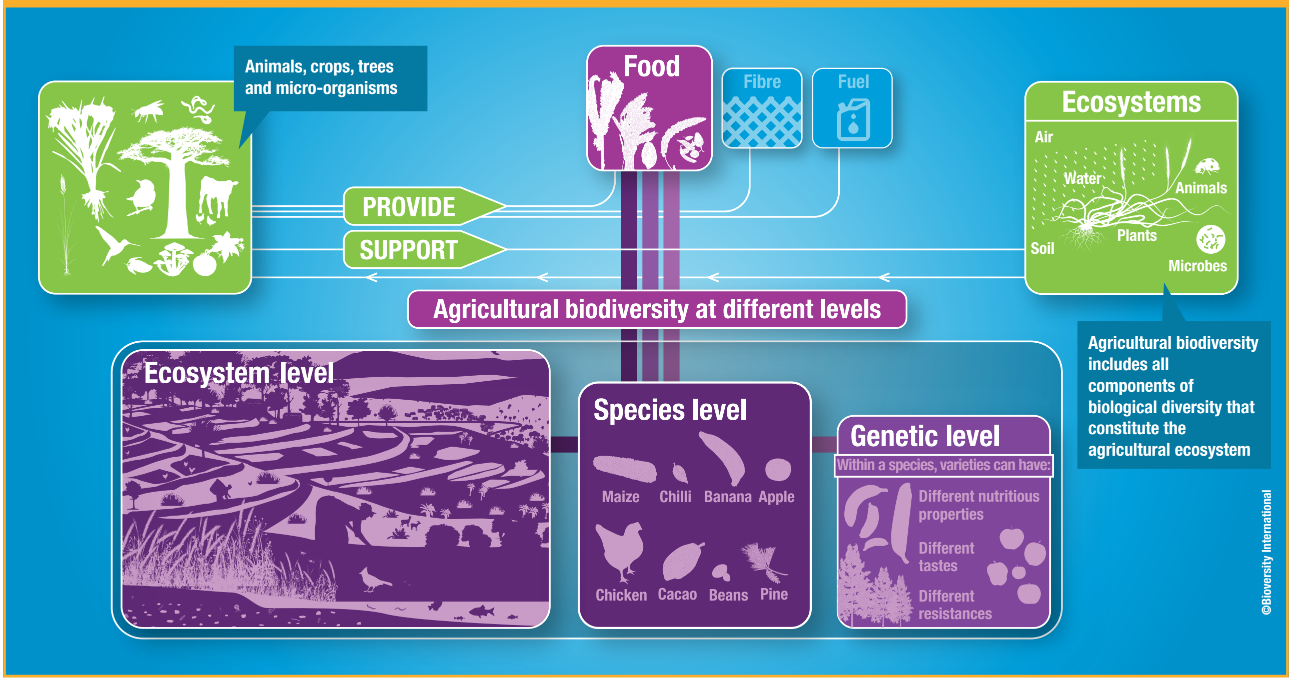
Introduction

In today's complex and interconnected world, what we eat and how we produce it are inextricably bound together. A focus on increasing food production without due concern for the environment is causing severe land and water degradation. A focus on addressing hunger without a focus on good nutrition is causing an epidemic of non-communicable diseases. A focus on increasing yields in a few staple food crops is contributing to loss of crop diversity. What we need is to be able to produce a wide variety of nutritious foods while having minimal impact on the environment – a sustainable food system. The Sustainable Development Goals, signed by 193 world leaders in 2015, recognize that these challenges are interconnected and multidimensional.

To address these complex and multifaceted problems, we need to transform our food systems both in the way we produce food and in what we choose to eat. Agricultural biodiversity (Figure 1.1) is an important resource for transforming agriculture. Agricultural biodiversity is the backbone of sustainable agricultural intensification (1, 2). For example, agroforestry, home gardens, integrated crop–livestock systems, mosaic land uses, intercropping, cover crops, integrated pest management and crop rotations all typically benefit from using agricultural biodiversity (Chapter 3). It is also a rich resource for year-round healthy, diverse diets by providing nutrient-rich species and varieties, which are often well adapted to local conditions. Increasing the number of food groups grown on farms is associated with greater diversity on the plate (Chapter 2). Households which grow a diverse set of crops are less likely to be poor than households that specialize in their crop production (3). Additionally, crop diversity reduces the probability that a non-poor household will fall into poverty and the probability that a poor household will remain in poverty (3). While agricultural biodiversity is by no means the only component needed in a sustainable food system, a sustainable food system cannot exist without agricultural biodiversity.

Using agricultural biodiversity in sustainable food systems can help to achieve multiple Sustainable Development Goals, and to meet several of the biodiversity targets set by the Convention on Biological Diversity (known as the Aichi Biodiversity Targets).[i] However, governments, the private sector and other decision-makers have no consistent way to assess and track agricultural biodiversity in sustainable food systems. Governments need to be able to identify opportunities for good investments and decisions, which satisfy human aspirations while protecting the natural resource base that underpins human well-being. Businesses too need "pragmatic but credible tools" in order to drive their practices towards sustainability (4). In short, we need metrics which can measure and compare key elements of food system sustainability. Measuring agricultural biodiversity is one powerful way to do this, since biodiversity is central to our agricultural systems, our diets, our environmental integrity and the livelihoods of farmers.

FIGURE 1.1 – What is agricultural biodiversity?



Credit: Bioversity International/P.Gallo

In this book, Bioversity International brings together scientific evidence of the role of agricultural biodiversity in creating a sustainable food system. Building on this evidence base, the book identifies a framework and candidate indicators for an 'Agrobiodiversity Index', a pragmatic and credible tool to measure and manage food system sustainability for the long term.

Drivers of change in our food systems

Recent assessments of trends and challenges driving change in food systems in the early 21st century agree that major drivers are climate change, depletion of natural resources, demographic changes and issues around food and nutrition security. These drivers – if no changes are made to our patterns of production and consumption – will increase the pressure on food systems beyond the capacity of the world to recover.

Demographic changes

The global population will grow from 7.4 billion now to about 9.3 billion people by 2050 (5). About a billion more people will live in Africa (6). The global middle class is expected to more than double in size to almost 5 billion by 2030, and two out of three people will live in a city (5). The world population is getting older; by 2100 young children will be 6% and older people 23% of the population (7).

Higher incomes, urbanization, a growing population and changing dietary patterns are driving intensified demand for increased production of food (7). This puts pressure on natural resources, and leads to high and volatile prices for commodities (rice, wheat, maize, soy, meat, oils, dairy and sugar), exacerbated by growing demand for more homogenous Western diets and for processed convenience foods (5). Both diets and agricultural systems have been greatly simplified over the past century. Within each individual country there has never been so much choice. For example, formal supermarkets in countries around the world offer avocado, quinoa and kiwi, which were not available 15 years ago. However, diets from one country to another are becoming more similar to each other, converging towards a Westernized diet based on major cereal crops, such as rice, wheat and maize, as well as sugar and oil (8). These crops increasingly dominate our agricultural production and therefore global food supplies (8). Sustained investment in producing more high-yielding starchy staples has led to a situation where of the 5,000–70,000 plant species documented as human food (Box 1.1), only three – rice, wheat and maize – provide half the world's plant-derived calories (10).

In much of the world, farmers are not benefiting from the growing demand for food. Within the agricultural sector, 800 million people live below the global poverty line (11).

BOX 1.1 – How many plant species are used for human food?

The exact number of plant species used for food is unknown and contested. The number depends on whether it includes both species found in the wild and those that are cultivated, which plant part is considered, potential and actual use, and whether species used for primarily medicinal purposes are counted. The Kew Royal Botanical Gardens *State of the World's Plants* report (9) summarizes data from 11 major databases and lists 'human food' (5,538 species) and 'medicines' (17,810 species) separately. Other authors suggest between 12,000 and 75,000 species (12, 13). A review in 2014 on 'plant diversity in addressing food, nutrition and medicinal needs' reported that "While the number of plant species used for food by pre-agricultural human societies is estimated at around 7,000 (14), another 70,000 are known to have edible parts (15). An estimated 50,000–70,000 plant species are used medicinally around the world (16, 17), of which relatively few are produced in cultivation (18)."(19, 20)

Climate change

The Intergovernmental Panel on Climate Change estimates total average global warming of over 1.3°C by 2040 (5). By 2100 it is expected to rise between 2.7°C and 3.7°C – far above the critical 2°C global target (11). Agriculture is not only affected by climate change, it is also a cause. Agriculture is responsible for about 21% of total global greenhouse gas emissions, mainly from changing land use, livestock production, and soil and nutrient management (7).

Climate change leads to changes in rainfall patterns and increases in extreme weather events across time and geography. In many of the poorest regions of the world, climate change will reduce crop yields and increase the incidence of animal diseases, leading to higher food prices (up to even 84% by 2050) (11), and insecurity for farmers, especially in low- and middle-income countries (5). In some areas – especially countries in tropical areas – rising temperatures can lead to some crops not being able to grow any more (7). Higher temperatures may affect the quality of food, with lower levels of zinc, iron and protein in some crops (7). They also lead to disruption in pollination and natural pest control, and degradation of soil and groundwater (7). Local extinctions of some fish species are expected near the equator (7, 21). In some areas, there will be new weather patterns, e.g. rains may be variable or late. Current yield-increasing methods such as using mineral fertilizers may be less effective under these new patterns (7). Climate change is expected to increase child malnutrition by 20% by 2050 (5). It will most affect rainfed smallholder farming systems in highlands and the tropics, i.e. 80% of the world's cropland and 60% of global agricultural output (7).

Depletion of natural resources

Natural resources include land, soil, water and biodiversity. Agriculture covers up to 38% of the Earth's surface (5) but 33% of the world's farmland is degraded (7). Agriculture accounts for 70% of all freshwater withdrawn (5, 7), and drives 80% of deforestation worldwide (7). The loss of forest and other wild biodiversity can lead to erosion of genetic diversity, which reduces options for breeding new plant varieties better adapted to climate change (7). The global food production system contributes around 24% of global greenhouse gas emissions (22, 23) and is the single largest user of fresh water on the planet (24). In addition, 62% of globally threatened species are negatively affected by agriculture (25). About 40% of the world's rural population lives in areas that are water scarce (7), yet demand for water is expected to rise by a further 40% by 2030. The effects of agriculture on natural resources are further exacerbated by climate change, changing diets, population growth and urbanization. Meat-rich diets drive depletion of natural resources through forest clearing for pastures and increasing methane emissions (7, 26).

Food and nutrition changes

Westernized diets put more pressure on natural resources; e.g. the production of 1kg of beef uses 12 times as much water as 1kg of wheat, and five times as much land (5, 27, 28). Modern diets are also linked to the triple burden of undernutrition, malnutrition and obesity (7). More than 2 billion people lack vital micronutrients (e.g. vitamins and minerals), and 2 billion are overweight or obese (5). Poor nutrition can lead to non-communicable diseases such as heart disease and type 2 diabetes, which are now the leading cause of death in all regions except Africa (11). In fact, 6 of the top 11 risk factors driving the global burden of disease are related to diet (6). This has real economic consequences: across Africa and Asia, the estimated impact of undernutrition on GDP is 11% a year (6). Intakes of pulses, fruits and vegetables are declining around the globe alongside a rising predominance of starches, meat and dairy (8). The supply of fruit and vegetables, nuts and seeds falls about 22% short of population requirements according to nutritional recommendations (29) with direct consequences for health.

Finding sustainable solutions

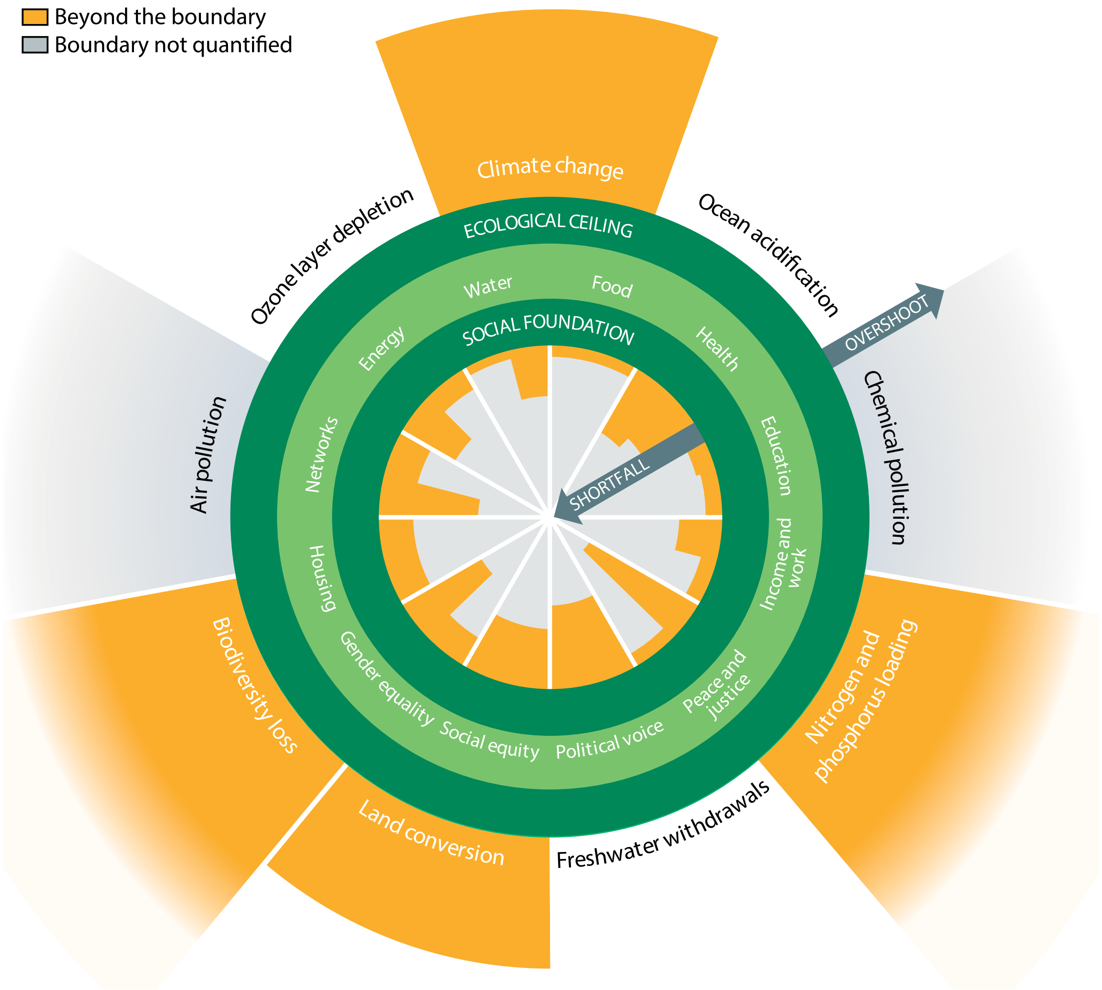
The global challenges related to the way we nourish a growing population while maintaining the health of our planet are intimately interconnected.

Sustainability is described in terms of accommodating three spheres: environmental integrity, social justice and economic growth. Addressing one or even two spheres alone often compromises the other sphere. For example, many of the great scientific strides to address food security in the 20th century, which have seen increases in the scale and short-term economic efficiencies of farming systems, did not take account of longer-term environmental or social concerns, leading to increased pressures on ecosystems and communities. Feeding the human population by improving the performance and yields of a limited number of staple crops and animal breeds, combined with intensive chemical inputs, is causing severe land degradation, air and water pollution (30, 31), and has led to a loss of biodiversity in supply chains and in farmers´ fields around the world (10, 32–34). Similarly, a focus on large-scale, intensive production of starchy crops for calories rather than for nutrition and healthy diets, has led to an epidemic of non-communicable diseases such as obesity and type 2 diabetes (35, 36). Moreover, although there has been a significant reduction of poverty globally, advances have been uneven. In many countries, even those that have reduced poverty at the national level, economic inequality is increasing and remains concentrated in rural areas (37).

To measure the environmental impacts of human activity on our planet, environmental scientists have developed the concept of 'planetary boundaries', which measure the boundaries for nine vital Earth system processes (e.g. biodiversity loss, climate change). We have to stay within those boundaries if the planet is to sustain human life in the long term (24, 38). For the social and economic spheres, social scientists have complemented these physical boundaries with social and economic boundaries – including decent jobs, access to education and gender equity – which also need to be respected for healthy societies (39). When both social foundations and environmental ceilings are respected, the world is in a "safe and just operating space for humanity to thrive" (39, Figure 1.2). We have already exceeded four planetary boundaries: biodiversity loss, climate change, land conversion and nitrogen and phosphorous loading (Box 1.2).

FIGURE 1.2 – A safe and just operating space for humanity

A safe and just operating space for humanity respects both planetary and social boundaries. The environmental ceiling consists of nine planetary boundaries, as set out by the Stockholm Resilience Centre. The social foundation consists of the eleven top social priorities identified by the world's governments in the run-up to Rio+20 (adapted from 39)



BOX 1.2 – What does it mean to exceed a planetary boundary?

The transgressing of planetary boundaries is far more than symbolic. The boundaries are scientifically derived levels of human-induced change, beyond which there is a risk of irreversible environmental change. This has serious implications for human society (38). Transgressing these boundaries creates considerable risk of moving planetary conditions outside of the relatively stable and benign conditions in which modern human civilization (including agriculture) developed and thrived. In the case of the planetary boundaries already shown to have been seriously (and potentially dangerously) transgressed, the risks and impacts include:

- Biodiversity loss: Reduction or loss of the many ecosystem services known to be generated from biological diversity, including future options for crop adaptation and collapse of pollination in some crop systems.
- Nitrogen loading: Increasing quantities of atmospheric nitrogen are converted into reactive nitrogen through human activities. Much of this reactive nitrogen is not taken up by plants, but leached into marine, aquatic and terrestrial systems as a pollutant, leading to potential and realized collapse of ecological systems (e.g. marine and coastal 'dead zones').

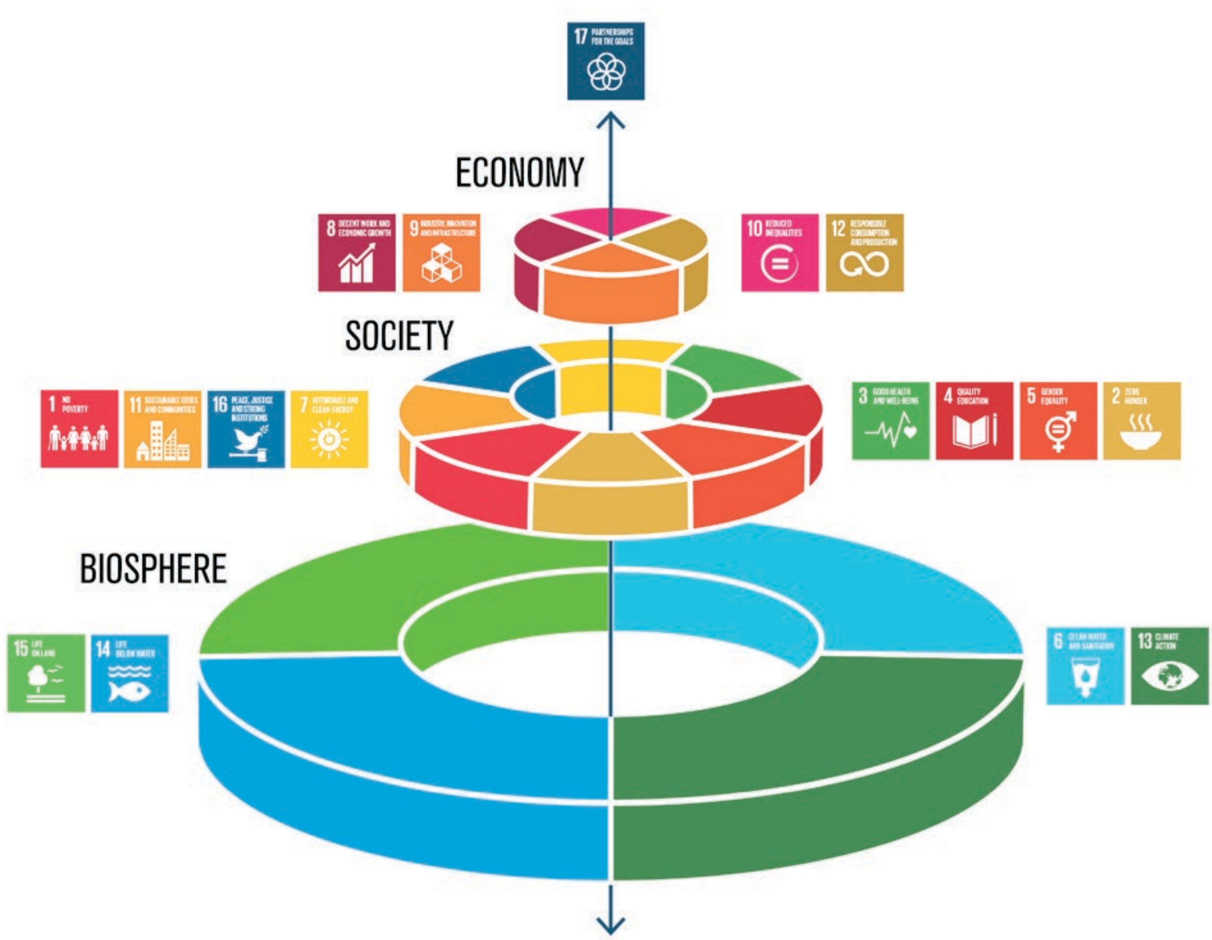
"What is required is a fundamentally different model of agriculture based on diversifying farms and farming landscapes."

International Panel of Experts on Sustainable Food Systems (40)

There is a global growing consensus that business as usual is not working, and it is time for a paradigm shift (6, 40). Solutions have to be as interconnected as the problems they seek to solve. The 2030 Agenda and its Sustainable Development Goals provide a framework for an 'integrated agenda', which means achieving multiple benefits at the same time – for example, including nutrition goals in farming systems; increasing yields without increasing the levels of inorganic and synthetic chemicals in the system; shaping landscapes which create positive synergies between wild and cultivated lands; improving environmental integrity while reducing poverty and gender inequality. The Sustainable Development Goals are indivisible and not hierarchical. However, none of the social and economic goals can be achieved if there is an inadequate natural physical resource base to sustain human life (Figure 1.3, 40, 42).

FIGURE 1.3 – A new way of picturing the Sustainable Development Goals: Linking the biosphere to sustainable and healthy food

In this representation of the Sustainable Development Goals, by the Stockholm Resilience Centre, the economy serves society, and both depend on the integrity of the biosphere. In this vision, all the Sustainable Development Goals are directly or indirectly connected to sustainable and healthy food.



Credit: Azote Images for Stockholm Resilience Centre

Rice terraces in Indonesia, a typical agricultural landscape of the region.
Credit: Bioversity International/M.Fancello

The contribution of agricultural biodiversity

One vital aspect of the biosphere resource base is agricultural biodiversity. Agricultural biodiversity is defined as "the variety and variability of animals, plants and micro-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, fibre, fuel and pharmaceuticals. It also includes the diversity of non-harvested species that support production (soil micro-organisms, predators, pollinators), and those in the wider environment that support agro-ecosystems (agricultural, pastoral, forest and aquatic) as well as the diversity of the agro-ecosystems" (43, Figure 1.1).

Agricultural biodiversity is the result of natural selection processes (e.g. adapting to changing weather patterns or particular land characteristics) that have been interwoven with the careful selection and inventive developments of farmers, forest dwellers, hunter-gatherers, herders and fishers over millennia (e.g. selecting for taste, ease of processing or harvesting) (42, 43). Managed knowledgeably, agricultural biodiversity provides resources and processes embedded in farming systems, which allow these systems to meet current food and nutrition needs (Chapter 2), while having minimal negative impact on the environment and generating multiple ecosystem services (45, Box 1.3, Chapter 3).

BOX 1.3 – What are ecosystem services?

Ecosystem services are defined as "the benefits people obtain from ecosystems. These include services such as food, water, timber and fibre (provisioning); services that affect climate, floods, disease, wastes and water quality (regulating); services that provide recreational, aesthetic and spiritual benefits (cultural). The human species, while buffered against environmental changes by culture and technology, is fundamentally dependent on the flow of ecosystem services."

Adapted from (45) following the Common International Classification of Ecosystem Services (CICES) categorization (46)

Because agricultural biodiversity has co-evolved with farming systems and breeding systems, it is already deeply integrated within these systems. Increasing what we know about agricultural biodiversity, its components and the interactions among them can help countries to leverage their existing resources and knowledge for integrated nutrition and environmental outcomes.

Agricultural biodiversity is, however, under threat. Despite the many benefits it provides, agricultural biodiversity is being lost as:

- Farming production systems have shifted to more intensive production practices which rely on fewer varieties, genes or species (10, 31, 47, 48)
- Traditional agricultural practices and knowledge are displaced (by intensive, external input-based management practices) and undervalued
- Climate change and land-use changes accelerate land degradation
- Value chains are under pressure to provide standard products year round in any country and any season.

Conservation approaches have been developed to stem biodiversity loss (Chapter 5) and seed systems strengthened to make sure that biodiversity is not only conserved, but also available and accessible when and where it is needed by those who need it for different purposes (Chapter 4).

"At the World Health Organization, we are aware of the growing body of evidence that biodiversity loss is happening at unprecedented rates. There is increasing recognition that this is a fundamental risk to the healthy and stable ecosystems that sustain all aspects of our societies."

Dr Maria Neira, Director, Public Health, Environmental & Social Determinants of Health (49)

Using agricultural biodiversity in sustainable food systems

'Sustainable food systems' are a relatively recent concept with various definitions. In July 2014, the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security of the Food and Agriculture Organization of the UN (FAO) defined a sustainable food systems as "a food system that delivers food security and nutrition for all in such a way that the economic, social and environmental bases to generate food security and nutrition for future generations are not compromised" (50).

'Using agricultural biodiversity' is the act of intentionally taking advantage of the variety and variability of plants, animals, landscapes and even soil organisms, to achieve certain goals. Using agricultural biodiversity can take many forms. It can mean identifying which plant species or varieties contain important traits, such as salinity resistance or nutrient density, and using them to breed new varieties. At the farm level, it can refer to farming practices in which genetically distinct varieties of the same species are planted together as a mixture to increase resistance to diseases, or planting different varieties in different areas of the same farm to respond to different micro-environments. It can mean planting certain varieties of a crop because they have particular nutritional or cooking qualities. Using agricultural biodiversity might entail integrated farming systems where animals, crops and trees interact, with benefits of increased yields, lower fertilizer requirements and more food groups available for healthy diets. It can also involve adopting certain farming practices such as intercropping or crop rotations, which promote beneficial interactions among species, like the *milpa* system in Central America where beans are planted together with maize and squash, an ancient agricultural method which combines crops that are nutritionally and environmentally complementary.

At a landscape level, using agricultural biodiversity refers to creating a mosaic of different land uses – managed forest, cultivated fields, waterways, hedges and copses – to create beneficial synergies, such as water capture, pest control or pollinator habitat. It often involves matching land use to land form and soil type in order to tailor production to land capability, and in so doing reduce land degradation such as soil erosion. At the same time, diversity in the landscape can ensure that different food groups (vegetables, tree fruit, animals, staples) are produced all year round. Using agricultural biodiversity draws on the local agroecological knowledge of women and men, embodied in the development and use of certain varieties, species and landscape patterns, together with the scientific knowledge of biologists, ecologists, zoologists and agronomists, among others, to create innovation. Using agricultural biodiversity often means a focus on locally specific species, breeds and varieties, which are not well known on a global scale and are under-represented in formal research (neglected and underutilized species), because of the variety and variability that they represent in a system, and their suitability to local environmental conditions and cultural requirements.

Using agricultural biodiversity can contribute to many vital aspects of a sustainable food system, in turn contributing to realization of several interconnected Sustainable Development Goals and Aichi Biodiversity Targets (Figure 1.4).

Kyanika women's group cooking traditional food, Kitui, Kenya.
Credit: Bioversity International/P.Sands

FIGURE 1.4 – Agricultural biodiversity contributes to many aspects of a sustainable food system, in turn contributing to realization of Aichi Biodiversity Targets and Sustainable Development Goals

Aichi Biodiversity Target Icons Copyright BIP/SCB

Credit: Bioversity International/P.Gallo/A.Del Castello

Mainstreaming agricultural biodiversity in sustainable food systems

Knowledge of the value of using agricultural biodiversity is a useful first step towards food system sustainability, but to have impact, practices need to be 'mainstreamed' into other sectors.

Under the Convention on Biological Diversity, mainstreaming biodiversity is defined as: "the integration of the conservation and sustainable use of biodiversity in cross-sectoral plans such as poverty reduction, sustainable development, climate change adaptation/mitigation, trade and international cooperation, as well as in sector-specific plans such as agriculture, fisheries, forestry, mining, energy, tourism, transport and others." (51)

In practice, mainstreaming means that specific components of biodiversity (e.g. genetic, varietal, species, landscape) are integrated into other sectors for the generation of mutual benefits. Examples are: linking tourism to biodiversity for conservation and economic returns; or using diversity in agriculture to increase productivity and resilience while at the same time conserving biodiversity. Integration may be into the plans, policies and practices of natural resource sectors, such as agriculture or forestry, or other economic and social sectors, such as poverty alleviation or climate adaptation. Methods can comprise changes in policies, plans or laws, public–private partnerships or communication campaigns (See Table 1.1).

TABLE 1.1 – A framework for mainstreaming biodiversity

Integrating biodiversity…		
Integrate the components of biodiversity in order to achieve specific biodiversity goals…	**Specific components of biodiversity:** • Genetic diversity • Species and their habitats • Populations and communities • Ecological processes, functions • Landscapes, ecosystems • Ecosystem goods and services	**For specific goals:** • Minimize or mitigate risk • Restore, improve or maintain ecological integrity • Ensure ecological resilience and adaptation • Maintain ecosystem services • Improve diet diversity year round
	…into sectoral plans and policies…	
…into the plans, policies and practices of natural resource sectors, and economic/social development sectors at all levels…	**Natural resource sectors:** • Agriculture • Forestry • Fisheries, aquaculture, marine • Freshwater, rivers • Grazing, grassland	**Economic and social development sectors:** • Poverty alleviation • Health • Climate adaptation • Private businesses • Food and water security • Financial investments
		…using a variety of methods
…through approaches that rely on changes in policies and plans, on economic instruments and on education, among other methods.	**Policy and plans:** • Reform or create policies, plans, laws • Create protected areas, buffer zones, corridors • Modify management plans and practices • Incorporate into strategic environmental assessments • Incorporate into spatial and land-use planning • Public–private partnerships • Market-based certification • Voluntary best practice	**Economic instruments, education, incentives, partnerships:** • Economic valuation • Payments for ecosystem services • Communication, education • Biodiversity offsets

Adapted from (52)

Mainstreaming agricultural biodiversity in food systems contributes to their sustainability and enables policymakers to make progress toward their commitments to the Sustainable Development Goals and the Aichi Biodiversity Targets. Governments make a difference through the food and agricultural policies they adopt. Corporations make a difference through the business models they select. Given the right policy environment, together with appropriate management actions and information, from the same starting point, different results are possible (Box 1.4). Policies and actions matter.

BOX 1.4 – Illustration of the effects of policies and institutional arrangements on outcomes

An analysis of the nexus between food security and biodiversity conservation in two distinct agricultural systems in the same geographical area in Brazil (Mato Grosso) noted that the interplay between institutions and policies from household to global scale resulted in one system with a monoculture of soybean and both low food security and low biodiversity; the other with a vibrant patchwork of family farms with various land-use types, and higher food security and biodiversity.

Although the two landscapes shared the same climate conditions, regional and national governments and regulatory frameworks, what made a difference was how these interacted with global, landscape and household institutions. The interactions between different sets of policies and social institutions at different scales allowed the two different outcomes to emerge. At the global level, in the monoculture case, the forces of commodity markets and rise of meat and biofuels predominated; in the family farms, it was demand for sustainably produced and socially equitable foods. At a regional level, for the monoculture, policy drivers were public financing for export commodity production (e.g. land, credit, subsidies); for the family farms, main drivers were Brazil's 'Zero Hunger' policies and investment in family farming (e.g. credit and market access). At the landscape level, monocultures were shaped by a concentration of wealth among a few producers; the family farms were shaped by marketing cooperatives, access to inputs and local market development. Finally, institutional drivers at a household level for the monoculture were access to chemical inputs and markets, and increased household income; for the family farms, they were access to inputs, access to knowledge and more stable household incomes.

The case study highlights how the interplay of multiple scale policies and management actions can influence biodiversity and food security outcomes.

Challenges of mainstreaming agricultural biodiversity

While the potential benefits are multiple, mainstreaming agricultural biodiversity in food systems is easier said than done.

First, using agricultural biodiversity is not a 'one size fits all' solution. On the contrary, it is complex. It is about the diversity of varieties, species and systems, and how to manage such a range of options for multiple objectives – income generation, nutrition, sustainable natural resources and risk mitigation. Mainstreaming agricultural biodiversity therefore requires a systems approach, which recognizes the connectivity among elements, multiple viewpoints and the multi-functionality of food systems.

Second, there is a clear tension between specialization for increasing productivity, cost-efficiency and reaching economies of scale, and diversification for risk mitigation and stability (Box 1.4). Specialization, with intensified production geared towards local, national or international markets, can foster transitions out of poverty and boost local economic development. But important trade-offs may exist in terms of livelihood security, gender equity and landscape resilience. For example, what has been called the 'curse of the cash crops' (54) points to how specialization in high-value crops for sale (which has long been a major development strategy) can lead to negative effects on food and nutrition security, thereby limiting sustainable pathways out of poverty (54–57). In contrast, livelihood and landscape diversification help minimize production and commercial risks, and smooth out income flows throughout the year (58). Crop diversification has been found to decrease the likelihood of falling into or remaining in poverty (3). Balancing the continuum between diversification and specialization is a critical consideration in livelihoods and landscape development.

Third, mainstreaming diversity across the food system requires new ways of cross-sectoral working. While an increasing number of government and private sector departments are embracing multidisciplinary approaches (e.g. Mexico, see page 15), the successful coordination and implementation of such efforts remains a challenge. Sector accountability and reward lines may not favour them working together and there may be competition among sectors for influence and resources.

Additionally, the way different sectors approach problems may be incompatible. For example, nutritionists generally are trained in a clinical tradition, and nutrition is often housed with the Ministry of Health, so a purely health focus will lack integration with agriculture and tend to overlook the role of food diversity and agricultural biodiversity in combatting malnutrition. Another example is the jurisdiction between Ministries of Agriculture and Environment (and sometimes Forestry) for lands falling under them. Different ministries will see plant diversity (such as the wild relatives of crops) in very different ways, leading to different expectations about policies and management regimes.

A fourth challenge for policymakers is current common measures of success. Success is usually measured within sector (e.g. nutrition outcomes, production outcomes or environment outcomes) without considering negative effects (or indeed positive synergies) on other sectors. In reality, policymakers have to engage in trade-offs and balancing acts among sector goals. (59, Box 1.5)

BOX 1.5 – Worked example. The wins and losses en route to zero hunger

In sub-Saharan Africa, ending hunger (Goal 2) interacts positively with several other goals – including poverty eradication (Goal 1), health promotion (Goal 3) and achieving quality education for all (Goal 4). Addressing chronic malnourishment is ‘indivisible’ from addressing poverty. Tackling malnourishment reinforces educational efforts because children can concentrate and perform better in school. Not addressing food security would counteract education, when the poorest children have to help provide food for the day.

Food production interacts with climate-change mitigation (Goal 13) in several ways, because agriculture represents 20–35% of total anthropogenic greenhouse-gas emissions. Climate mitigation constrains some types of food production; in particular those related to meat (methane release from livestock constitutes nearly 40% of the global agricultural sector’s total emissions). Yet food production is reinforced by a stable climate. Securing food from fisheries is also reinforced by protecting the climate, because that limits ocean warming and acidification.

Finally, in some parts of sub-Saharan Africa, promoting food production can also constrain renewable-energy production (Goal 7) and terrestrial ecosystem protection (Goal 15) by competing for water and land. Conversely, limited land availability constrains agricultural production.

The difficulty is compounded by large evidence gaps on the dynamic links between elements of a food system and long-term nutrition and sustainability outcomes.

Examples of successful mainstreaming

Despite these challenges, however, mainstreaming of agricultural biodiversity (i.e. the integration of agricultural biodiversity in other sector-specific plans) can be done.

Mainstreaming agricultural biodiversity into nutrition programmes

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 Zero Hunger Strategy umbrella and strategically targeting relevant public policies and instruments that can facilitate agricultural biodiversity mainstreaming. Public policies – such as the National School Meals Programme and the Promotion of Socio-biodiversity Product Chains among several others – provide entry points for potentially improving nutrition or livelihoods with links to native agricultural biodiversity. Results include new dietary guidelines that take into account healthy diets derived from socially and environmentally sustainable food systems. The guidelines support multiple small retail channels, including those using organic and agroecological methods, and family farming. Further outcomes can be seen in the national budget for 2016–2019, which includes many objectives, targets and initiatives related to the sustainable use of biodiversity for food and nutrition (e.g. promoting biodiversity products in public purchases from family farming) (60).

Mainstreaming agricultural biodiversity into agricultural production

UN Environment from 2004 to 2014 assisted 47 countries in Africa, Asia and Latin America to mainstream agricultural biodiversity conservation and sustainable use in the agriculture production sector. The projects were implemented in biodiversity-rich areas with globally significant agricultural ecosystems and where agricultural biodiversity is central to the livelihood strategies of small-scale farmers, rural communities and indigenous peoples. Projects demonstrated sustainable agricultural management practices that directly contributed to the conservation and sustainable use of agricultural biodiversity on 1,254,564ha of land. As a result of the mainstreaming interventions, the governments of partner countries developed supportive strategies and policies and regulatory frameworks that address the mainstreaming of agricultural biodiversity in different ways (61). For success in integrating biodiversity in agricultural production systems, partnerships and community engagement have been found to be fundamental (62). Partnerships need to be between different institutions (e.g. private sector, research, national governments) and between different disciplines (e.g. ecology, conservation, breeding, human health). Community institutions, such as farmer organizations and women's associations, make sure that actions reflect local needs and are grounded in local context (62).

Mainstreaming conservation of agricultural biodiversity across sectors of national government

Mexico is a federal republic and most biodiversity issues are federal matters with regulations generated at the federal level but implemented and managed by the state and local governments. The Secretariat of Environment and Natural Resources is responsible for the conservation and sustainable use of biodiversity. The Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA) has functions which influence the conservation of biodiversity at three levels: ecosystem, species and genetic diversity. To mainstream biodiversity into cross-sectoral policies, interdepartmental and crosscutting commissions for biodiversity and sustainable development were put into action with mostly different functions: one agency, the National Commission for Knowledge and Use of Biodiversity (CONABIO) charged with information and knowledge generation; one commission, chaired by the Head of SAGARPA and including representatives of the Secretaries of State to coordinate rural development interagency participation from the whole country and boost concurrent regional projects for rural development; and the third, a large, broad-based Mexican Council for Sustainable Rural Development, with representatives from most national sectors (including rural, agriculture and social) and private sectors, as well as academia and NGOs, charged with an advisory role to the federal government. These structures provide an important opportunity to internalize the value of the natural capital of Mexico in all activities of the public sector and of society at large (63).

Picking *Garcinia indica* from trees in the forest near a village of the Western Ghats, India. *G. indica* has a distinctive flavour and medicinal properties. Its dried rind is used as a flavouring agent, while the seeds are a rich source of an edible fat. As a wild tree, it has no need of irrigation, pesticides or fertilizers. Of the 35 species of *Garcinia* reported in India, seven are endemic to the Western Ghats region. However, unsustainable harvesting is common and causing rapid erosion of valuable types. Credit: Bioversity International/E.Hermanowicz

The Agrobiodiversity Index

Governments, businesses and investors seeking to drive food system practices and policies towards sustainability need a way to visualize the links between different elements of a food system at various scales and time frames, in order to make decisions on ways to sustainably achieve nutrition and environmental goals. Bioversity International, with a wide range of partners, is developing an 'Agrobiodiversity Index' to help policymakers and other interested parties to assess dimensions of agricultural biodiversity in order to guide interventions and investments for food systems that are sustainable and nutritious. The Index will:

- Be actionable, helping different stakeholders understand where best to intervene for multiple outcomes, along a desired pathway towards sustainability
- Simplify complexity, guiding policymakers to balance long- and short-term goals in situations of multiple sectors and multiple stakeholders in order to see promising intervention points for sustainable and healthy outcomes
- Integrate multiple disciplines and sectors, and the needs of different stakeholders from farmers to economists, nutritionists and social development practitioners
- Be based on scientific principles and evidence to make sure that analyses are as robust and rigorous as possible
- Be subject to iterative improvements based on review, user feedback and scientific advancements.

This book outlines the proposed dimensions of the composite Agrobiodiversity Index:

- Healthy, diverse diets
- Sustainable farming systems
- Diversity-supplying seed systems
- Conservation of agricultural biodiversity

Each dimension represents well-researched systems in their own right – nutrition systems, production systems, seed systems and conservation systems – but which are: (1) rarely considered together and (2) often not considered in terms of the multiple roles of agricultural biodiversity. Agricultural biodiversity can be a potent way to link these systems and leverage synergies among them.

The first two dimensions address one key aspect of a sustainable food system: how to integrate issues of consumption and production. We take these as the starting point of this book. From the consumption side, our interest is in when and how agricultural biodiversity can contribute to attaining healthy and diverse diets, which provide the basis for good nutrition status. From the production side, the focus is on the role of agricultural biodiversity in supporting production systems that provide not only high yields, but also multiple benefits, such as cultural values, environmental integrity and human welfare (64). We also explore components, such as on-farm biodiversity, which can be sources simultaneously of healthy, diverse diets and multifunctional farming systems, not to mention often supporting sociocultural identity and heritage.

To support the coupled needs of diets and farming systems, agricultural biodiversity has to be made available and accessible to potential users and adequately conserved. From this, emerge the third and fourth dimensions of the Index: diversity-supplying seed systems and conservation of agricultural biodiversity. Seed systems address issues of how seeds and other planting materials get to where they are needed to support nutritious, healthy diets and multifunctional production landscapes in sufficient quantity, quality and diversity. For conservation, the focus is on what diversity needs to be conserved to support sustainable food systems, how and where it should be conserved, and who needs to play a role in conserving it.

The authors of the book take the country as the main unit of analysis.[ii] However, the vision of the Agrobiodiversity Index is that it be designed with the flexibility to be tailored to the needs of other stakeholders (such as the financial sector, businesses or companies) at different scales and levels.

Each of the following four chapters outlines evidence of the role of agricultural biodiversity in one dimension of the Index, and any existing evidence gaps that need to be filled. The intention is to draw on a wide range of literature to present the core ideas around each dimension rather than conduct and present a systematic review or meta-analysis. Given the different nature of each dimension, each chapter focuses on different components and scales of agricultural biodiversity (Table 1.2).

TABLE 1.2 – Summary of components of agricultural biodiversity covered in each chapter

Chapter focus	Components of agricultural biodiversity addressed	Key areas to consider
Healthy, diverse diets	All diversity used for food – cultivated plants, domesticated animals, aquatic species and foods from the wild. Both among-species and within-species diversity	Nutritional composition of food biodiversity Food biodiversity on farm Food biodiversity in the wild Food biodiversity in markets Market diversity
Multiple benefits from sustainable farming systems	The diversity among and within cultivated plants, and their interactions with other elements of biodiversity (e.g. pollinators, soil fauna), including interactions between cultivated and wild biodiversity. Levels of diversity from genetic and species to farm and ecosystem	Agricultural biodiversity and… - Soil erosion control - Pest and disease control - Pollination - Wild biodiversity conservation - Soil quality - Yield of crops for food - Resilient agricultural landscapes
Diversity-supplying seed systems	Crop and food tree diversity, among and within species	Seed access Seed production and distribution Seed innovation Seed regulation
Conservation of agricultural biodiversity	The major components of farming systems for food – food crops and their many varieties, and domesticated animals. Both among-species and within-species diversity	On-farm conservation *In situ* conservation in the wild *Ex situ* conservation

The authors lay out the evidence for the role of agricultural biodiversity in each dimension and describe evidence of key areas to consider. They also reflect on how to assess and track each of these essential areas, proposing a set of candidate indicators for the Agrobiodiversity Index, selected through application of the criteria developed by the Biodiversity Indicators Partnership (BIP) (65): [iii]

- Scientifically valid: (a) there is an accepted theory of the relationship between the indicator and its purpose, with agreement that change in the indicator does indicate change in the issue of concern; (b) the data used is reliable and verifiable
- Based on available data so that the indicator can be produced regularly over time
- Responsive to change in the issue of interest
- Easily understandable: (a) conceptually, how the measure relates to the purpose, (b) in its presentation, and (c) the interpretation of the data
- Relevant to users' needs
- 'Championed' by an institution responsible for the indicator's continued production and communication
- Used: for measuring progress, early warning of problems, understanding an issue, reporting, awareness raising, etc.

The final chapter draws on the evidence presented to propose a framework for the Agrobiodiversity Index and compile a first set of candidate indicators for discussion with stakeholders. This chapter outlines the processes and inputs, including stakeholder conversations, analyses and indicator refinement, followed to develop this cost-efficient, robust and usable tool for all those seeking increased food system sustainability.

Conclusions

"...we highlight the close link between climate change, sustainable agriculture and food and nutrition security with the message that 'The climate is changing. Food and agriculture must too.' Without concerted action, millions more people could fall into poverty and hunger, threatening to reverse hard-won gains and placing in jeopardy our ability to achieve the Sustainable Development Goals."

Ban Ki-moon, World Food Day statement, October 2016

It is imperative for the world to change practices to get on a more sustainable route. The 2030 Agenda for Sustainable Development recognizes this necessity and suggests integrated targets which bring together indivisible goals of economic, social and environmental progress. To tackle these, new approaches are needed. In the context of sustainable food systems – which deliver food security and nutrition for all in such a way that the economic, social and environmental bases to generate food security and nutrition for future generations are not compromised – agricultural biodiversity is a key resource. While agricultural biodiversity alone is not the sum and breadth of a sustainable food system – many other elements are needed, such as sustainable agronomic practices and socially just working conditions for agricultural workers – it is also true that it is impossible to have a sustainable food system without agricultural biodiversity, since it represents the foundations of agriculture.

Although there have been calls now for over a decade to mainstream biodiversity into nutrition, farming and forestry, policymakers often find it difficult to identify what that means in practice and how to intervene. Many indicators exist for individually or separately measuring biodiversity conservation, production system effectiveness, ecosystem health and human nutrition (66). The Agrobiodiversity Index is being developed as a tool for integrating an evidence-based selection of these indicators into one composite index which offers visualization and assessment across multiple aspects of a sustainable food system. No other index exists which integrates agricultural biodiversity issues across genetic resource management, production and consumption in food systems. It will combine large-scale quantitative data sources, with granular crowdsourced data, qualitative insights and assessments of policies and programmes in order to identify leverage points for action. The Agrobiodiversity Index will be designed to be flexible to the needs of different users. It will help countries to track progress towards several Sustainable Development Goals and Aichi Biodiversity Targets. It will also be designed for companies and for public and private investors interested in more sustainable practices in business and finance. The index can also provide information to farmer and consumer associations, to inform their decisions about sustainable practices or as a basis for a call to collective action.

Notes

[i] The Convention on Biological Diversity is one of three 'Rio Conventions' along with the United Nations Convention to Combat Desertification and the United Nations Framework Convention on Climate Change. The three conventions derive directly from the 1992 Earth Summit. Each instrument represents a way of contributing to the Sustainable Development Goals of Agenda 21 (the action plan of the United Nations with regard to sustainable development). The three conventions are intrinsically linked, operating in the same ecosystems and addressing interdependent issues. While not addressed directly in this book, agricultural biodiversity is also a component of efforts to combat desertification and tackle climate change challenges (through both mitigation and adaptation). See www.cbd.int/rio/

[ii] We recognize that environmental and agricultural issues are rarely confined to national borders – species populations can span many countries, environmental problems do not respect country borders, and countries are interdependent when it comes to sharing genetic resources. Furthermore differences in country size – e.g. between China and Costa Rica – can make country comparisons challenging. However, since most policy is taken at national level, we have selected this as the best unit for interventions.

[iii] The Biodiversity Indicators Partnership is a global initiative to promote and coordinate the development and delivery of biodiversity indicators for use by the Convention on Biological Diversity (CBD) and other biodiversity-related conventions, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), the Sustainable Development Goals (SDGs) and national and regional agencies. The Partnership currently brings together over 50 organizations working internationally on indicator development to provide the most comprehensive information on biodiversity trends. See www.bipindicators.net/.

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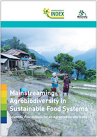
Traditional Sri Lankan dishes, paired with the vegetables used.
Credit: Bioversity International/S.Landersz


INDEX
Mainstreaming Agrobiodiversity in Sustainable Food Systems
Scientific Foundations for an Agrobiodiversity Index

Agricultural biodiversity and food system sustainability

M. Ann Tutwiler, Arwen Bailey, Simon Attwood, Roseline Remans, Marleni Ramirez

Transformation

KEY MESSAGES:

- → Food systems need to be reformed so that they nourish people while nurturing the environment.
- → Agricultural biodiversity is a source of nutritious foods which are culturally acceptable and often adapted to local and low-input agricultural systems. It is also a source of important traits for breeding resilient, nutritious crops and animal breeds.
- → Agricultural biodiversity is already a key component of farming systems and breeding systems worldwide.
- → The Agrobiodiversity Index will help policymakers and the private sector to assess dimensions of agricultural biodiversity to guide interventions and investments for sustainable food systems.

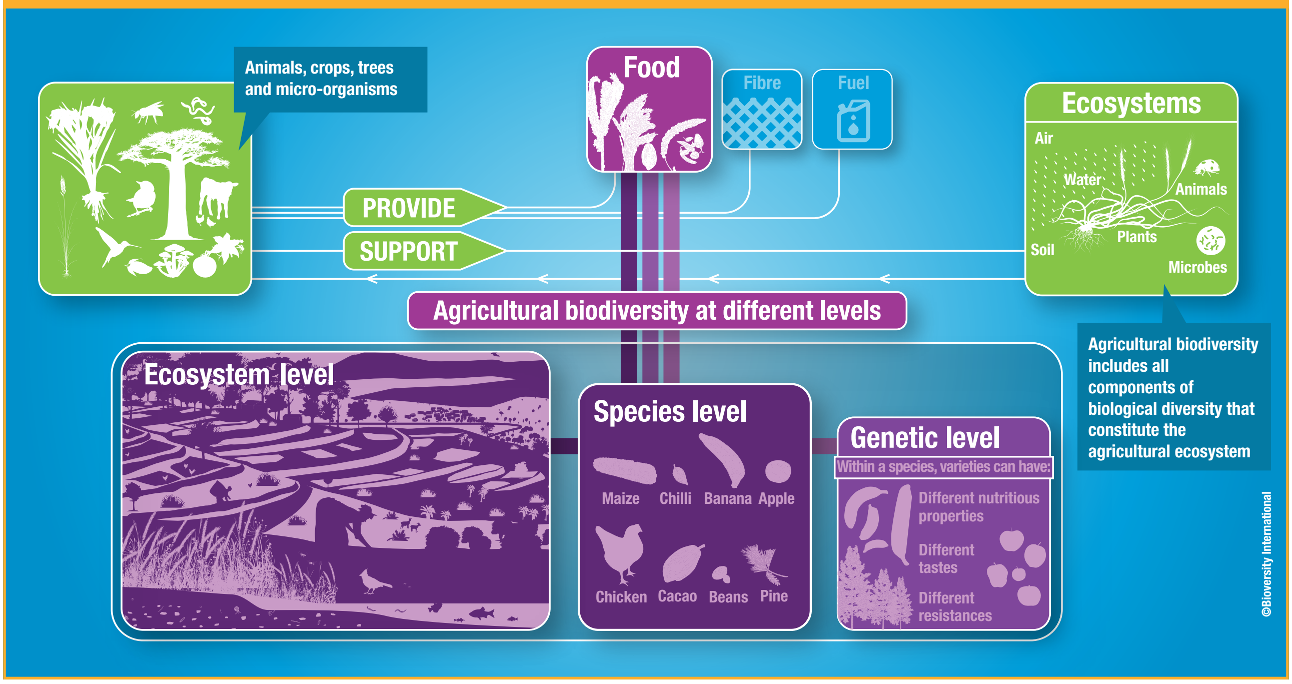
Introduction

In today's complex and interconnected world, what we eat and how we produce it are inextricably bound together. A focus on increasing food production without due concern for the environment is causing severe land and water degradation. A focus on addressing hunger without a focus on good nutrition is causing an epidemic of non-communicable diseases. A focus on increasing yields in a few staple food crops is contributing to loss of crop diversity. What we need is to be able to produce a wide variety of nutritious foods while having minimal impact on the environment – a sustainable food system. The Sustainable Development Goals, signed by 193 world leaders in 2015, recognize that these challenges are interconnected and multidimensional.

To address these complex and multifaceted problems, we need to transform our food systems both in the way we produce food and in what we choose to eat. Agricultural biodiversity (Figure 1.1) is an important resource for transforming agriculture. Agricultural biodiversity is the backbone of sustainable agricultural intensification (1, 2). For example, agroforestry, home gardens, integrated crop–livestock systems, mosaic land uses, intercropping, cover crops, integrated pest management and crop rotations all typically benefit from using agricultural biodiversity (Chapter 3). It is also a rich resource for year-round healthy, diverse diets by providing nutrient-rich species and varieties, which are often well adapted to local conditions. Increasing the number of food groups grown on farms is associated with greater diversity on the plate (Chapter 2). Households which grow a diverse set of crops are less likely to be poor than households that specialize in their crop production (3). Additionally, crop diversity reduces the probability that a non-poor household will fall into poverty and the probability that a poor household will remain in poverty (3). While agricultural biodiversity is by no means the only component needed in a sustainable food system, a sustainable food system cannot exist without agricultural biodiversity.

Using agricultural biodiversity in sustainable food systems can help to achieve multiple Sustainable Development Goals, and to meet several of the biodiversity targets set by the Convention on Biological Diversity (known as the Aichi Biodiversity Targets).[i] However, governments, the private sector and other decision-makers have no consistent way to assess and track agricultural biodiversity in sustainable food systems. Governments need to be able to identify opportunities for good investments and decisions, which satisfy human aspirations while protecting the natural resource base that underpins human well-being. Businesses too need "pragmatic but credible tools" in order to drive their practices towards sustainability (4). In short, we need metrics which can measure and compare key elements of food system sustainability. Measuring agricultural biodiversity is one powerful way to do this, since biodiversity is central to our agricultural systems, our diets, our environmental integrity and the livelihoods of farmers.

FIGURE 1.1 – What is agricultural biodiversity?



Credit: Bioversity International/P.Gallo

In this book, Bioversity International brings together scientific evidence of the role of agricultural biodiversity in creating a sustainable food system. Building on this evidence base, the book identifies a framework and candidate indicators for an 'Agrobiodiversity Index', a pragmatic and credible tool to measure and manage food system sustainability for the long term.

Drivers of change in our food systems

Recent assessments of trends and challenges driving change in food systems in the early 21st century agree that major drivers are climate change, depletion of natural resources, demographic changes and issues around food and nutrition security. These drivers – if no changes are made to our patterns of production and consumption – will increase the pressure on food systems beyond the capacity of the world to recover.

Demographic changes

The global population will grow from 7.4 billion now to about 9.3 billion people by 2050 (5). About a billion more people will live in Africa (6). The global middle class is expected to more than double in size to almost 5 billion by 2030, and two out of three people will live in a city (5). The world population is getting older; by 2100 young children will be 6% and older people 23% of the population (7).

Higher incomes, urbanization, a growing population and changing dietary patterns are driving intensified demand for increased production of food (7). This puts pressure on natural resources, and leads to high and volatile prices for commodities (rice, wheat, maize, soy, meat, oils, dairy and sugar), exacerbated by growing demand for more homogenous Western diets and for processed convenience foods (5). Both diets and agricultural systems have been greatly simplified over the past century. Within each individual country there has never been so much choice. For example, formal supermarkets in countries around the world offer avocado, quinoa and kiwi, which were not available 15 years ago. However, diets from one country to another are becoming more similar to each other, converging towards a Westernized diet based on major cereal crops, such as rice, wheat and maize, as well as sugar and oil (8). These crops increasingly dominate our agricultural production and therefore global food supplies (8). Sustained investment in producing more high-yielding starchy staples has led to a situation where of the 5,000–70,000 plant species documented as human food (Box 1.1), only three – rice, wheat and maize – provide half the world's plant-derived calories (10).

In much of the world, farmers are not benefiting from the growing demand for food. Within the agricultural sector, 800 million people live below the global poverty line (11).

BOX 1.1 – How many plant species are used for human food?

The exact number of plant species used for food is unknown and contested. The number depends on whether it includes both species found in the wild and those that are cultivated, which plant part is considered, potential and actual use, and whether species used for primarily medicinal purposes are counted. The Kew Royal Botanical Gardens *State of the World's Plants* report (9) summarizes data from 11 major databases and lists 'human food' (5,538 species) and 'medicines' (17,810 species) separately. Other authors suggest between 12,000 and 75,000 species (12, 13). A review in 2014 on 'plant diversity in addressing food, nutrition and medicinal needs' reported that "While the number of plant species used for food by pre-agricultural human societies is estimated at around 7,000 (14), another 70,000 are known to have edible parts (15). An estimated 50,000–70,000 plant species are used medicinally around the world (16, 17), of which relatively few are produced in cultivation (18)."(19, 20)

Climate change

The Intergovernmental Panel on Climate Change estimates total average global warming of over 1.3°C by 2040 (5). By 2100 it is expected to rise between 2.7°C and 3.7°C – far above the critical 2°C global target (11). Agriculture is not only affected by climate change, it is also a cause. Agriculture is responsible for about 21% of total global greenhouse gas emissions, mainly from changing land use, livestock production, and soil and nutrient management (7).

Climate change leads to changes in rainfall patterns and increases in extreme weather events across time and geography. In many of the poorest regions of the world, climate change will reduce crop yields and increase the incidence of animal diseases, leading to higher food prices (up to even 84% by 2050) (11), and insecurity for farmers, especially in low- and middle-income countries (5). In some areas – especially countries in tropical areas – rising temperatures can lead to some crops not being able to grow any more (7). Higher temperatures may affect the quality of food, with lower levels of zinc, iron and protein in some crops (7). They also lead to disruption in pollination and natural pest control, and degradation of soil and groundwater (7). Local extinctions of some fish species are expected near the equator (7, 21). In some areas, there will be new weather patterns, e.g. rains may be variable or late. Current yield-increasing methods such as using mineral fertilizers may be less effective under these new patterns (7). Climate change is expected to increase child malnutrition by 20% by 2050 (5). It will most affect rainfed smallholder farming systems in highlands and the tropics, i.e. 80% of the world's cropland and 60% of global agricultural output (7).

Depletion of natural resources

Natural resources include land, soil, water and biodiversity. Agriculture covers up to 38% of the Earth's surface (5) but 33% of the world's farmland is degraded (7). Agriculture accounts for 70% of all freshwater withdrawn (5, 7), and drives 80% of deforestation worldwide (7). The loss of forest and other wild biodiversity can lead to erosion of genetic diversity, which reduces options for breeding new plant varieties better adapted to climate change (7). The global food production system contributes around 24% of global greenhouse gas emissions (22, 23) and is the single largest user of fresh water on the planet (24). In addition, 62% of globally threatened species are negatively affected by agriculture (25). About 40% of the world's rural population lives in areas that are water scarce (7), yet demand for water is expected to rise by a further 40% by 2030. The effects of agriculture on natural resources are further exacerbated by climate change, changing diets, population growth and urbanization. Meat-rich diets drive depletion of natural resources through forest clearing for pastures and increasing methane emissions (7, 26).

Food and nutrition changes

Westernized diets put more pressure on natural resources; e.g. the production of 1kg of beef uses 12 times as much water as 1kg of wheat, and five times as much land (5, 27, 28). Modern diets are also linked to the triple burden of undernutrition, malnutrition and obesity (7). More than 2 billion people lack vital micronutrients (e.g. vitamins and minerals), and 2 billion are overweight or obese (5). Poor nutrition can lead to non-communicable diseases such as heart disease and type 2 diabetes, which are now the leading cause of death in all regions except Africa (11). In fact, 6 of the top 11 risk factors driving the global burden of disease are related to diet (6). This has real economic consequences: across Africa and Asia, the estimated impact of undernutrition on GDP is 11% a year (6). Intakes of pulses, fruits and vegetables are declining around the globe alongside a rising predominance of starches, meat and dairy (8). The supply of fruit and vegetables, nuts and seeds falls about 22% short of population requirements according to nutritional recommendations (29) with direct consequences for health.

Finding sustainable solutions

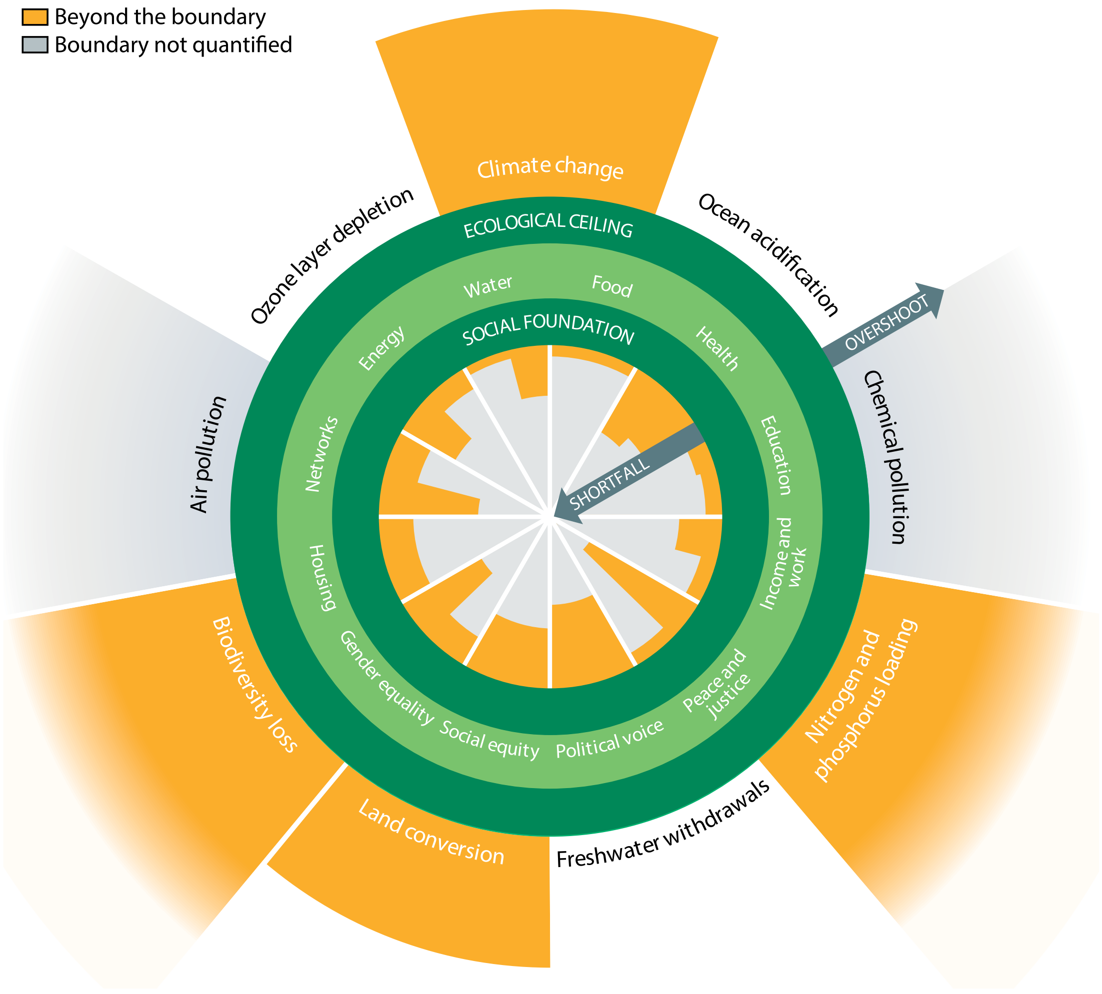
The global challenges related to the way we nourish a growing population while maintaining the health of our planet are intimately interconnected.

Sustainability is described in terms of accommodating three spheres: environmental integrity, social justice and economic growth. Addressing one or even two spheres alone often compromises the other sphere. For example, many of the great scientific strides to address food security in the 20th century, which have seen increases in the scale and short-term economic efficiencies of farming systems, did not take account of longer-term environmental or social concerns, leading to increased pressures on ecosystems and communities. Feeding the human population by improving the performance and yields of a limited number of staple crops and animal breeds, combined with intensive chemical inputs, is causing severe land degradation, air and water pollution (30, 31), and has led to a loss of biodiversity in supply chains and in farmers´ fields around the world (10, 32–34). Similarly, a focus on large-scale, intensive production of starchy crops for calories rather than for nutrition and healthy diets, has led to an epidemic of non-communicable diseases such as obesity and type 2 diabetes (35, 36). Moreover, although there has been a significant reduction of poverty globally, advances have been uneven. In many countries, even those that have reduced poverty at the national level, economic inequality is increasing and remains concentrated in rural areas (37).

To measure the environmental impacts of human activity on our planet, environmental scientists have developed the concept of 'planetary boundaries', which measure the boundaries for nine vital Earth system processes (e.g. biodiversity loss, climate change). We have to stay within those boundaries if the planet is to sustain human life in the long term (24, 38). For the social and economic spheres, social scientists have complemented these physical boundaries with social and economic boundaries – including decent jobs, access to education and gender equity – which also need to be respected for healthy societies (39). When both social foundations and environmental ceilings are respected, the world is in a "safe and just operating space for humanity to thrive" (39, Figure 1.2). We have already exceeded four planetary boundaries: biodiversity loss, climate change, land conversion and nitrogen and phosphorous loading (Box 1.2).

FIGURE 1.2 – A safe and just operating space for humanity

A safe and just operating space for humanity respects both planetary and social boundaries. The environmental ceiling consists of nine planetary boundaries, as set out by the Stockholm Resilience Centre. The social foundation consists of the eleven top social priorities identified by the world's governments in the run-up to Rio+20 (adapted from 39)



BOX 1.2 – What does it mean to exceed a planetary boundary?

The transgressing of planetary boundaries is far more than symbolic. The boundaries are scientifically derived levels of human-induced change, beyond which there is a risk of irreversible environmental change. This has serious implications for human society (38). Transgressing these boundaries creates considerable risk of moving planetary conditions outside of the relatively stable and benign conditions in which modern human civilization (including agriculture) developed and thrived. In the case of the planetary boundaries already shown to have been seriously (and potentially dangerously) transgressed, the risks and impacts include:

- Biodiversity loss: Reduction or loss of the many ecosystem services known to be generated from biological diversity, including future options for crop adaptation and collapse of pollination in some crop systems.
- Nitrogen loading: Increasing quantities of atmospheric nitrogen are converted into reactive nitrogen through human activities. Much of this reactive nitrogen is not taken up by plants, but leached into marine, aquatic and terrestrial systems as a pollutant, leading to potential and realized collapse of ecological systems (e.g. marine and coastal 'dead zones').

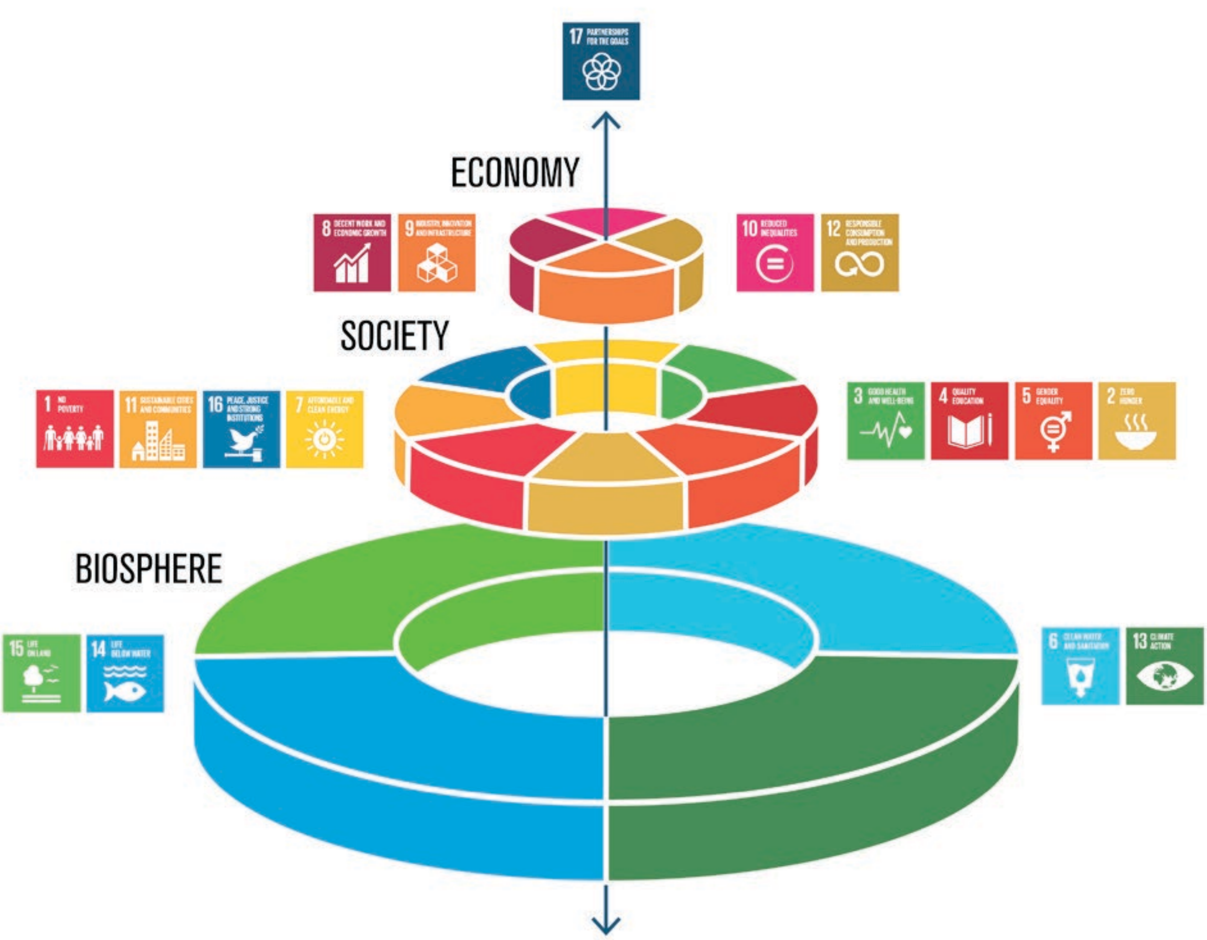
"What is required is a fundamentally different model of agriculture based on diversifying farms and farming landscapes."

International Panel of Experts on Sustainable Food Systems (40)

There is a global growing consensus that business as usual is not working, and it is time for a paradigm shift (6, 40). Solutions have to be as interconnected as the problems they seek to solve. The 2030 Agenda and its Sustainable Development Goals provide a framework for an 'integrated agenda', which means achieving multiple benefits at the same time – for example, including nutrition goals in farming systems; increasing yields without increasing the levels of inorganic and synthetic chemicals in the system; shaping landscapes which create positive synergies between wild and cultivated lands; improving environmental integrity while reducing poverty and gender inequality. The Sustainable Development Goals are indivisible and not hierarchical. However, none of the social and economic goals can be achieved if there is an inadequate natural physical resource base to sustain human life (Figure 1.3, 40, 42).

FIGURE 1.3 – A new way of picturing the Sustainable Development Goals: Linking the biosphere to sustainable and healthy food

In this representation of the Sustainable Development Goals, by the Stockholm Resilience Centre, the economy serves society, and both depend on the integrity of the biosphere. In this vision, all the Sustainable Development Goals are directly or indirectly connected to sustainable and healthy food.



Credit: Azote Images for Stockholm Resilience Centre

Rice terraces in Indonesia, a typical agricultural landscape of the region.
Credit: Bioversity International/M.Fancello

The contribution of agricultural biodiversity

One vital aspect of the biosphere resource base is agricultural biodiversity. Agricultural biodiversity is defined as "the variety and variability of animals, plants and micro-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, fibre, fuel and pharmaceuticals. It also includes the diversity of non-harvested species that support production (soil micro-organisms, predators, pollinators), and those in the wider environment that support agro-ecosystems (agricultural, pastoral, forest and aquatic) as well as the diversity of the agro-ecosystems" (43, Figure 1.1).

Agricultural biodiversity is the result of natural selection processes (e.g. adapting to changing weather patterns or particular land characteristics) that have been interwoven with the careful selection and inventive developments of farmers, forest dwellers, hunter-gatherers, herders and fishers over millennia (e.g. selecting for taste, ease of processing or harvesting) (42, 43). Managed knowledgeably, agricultural biodiversity provides resources and processes embedded in farming systems, which allow these systems to meet current food and nutrition needs (Chapter 2), while having minimal negative impact on the environment and generating multiple ecosystem services (45, Box 1.3, Chapter 3).

BOX 1.3 – What are ecosystem services?

Ecosystem services are defined as "the benefits people obtain from ecosystems. These include services such as food, water, timber and fibre (provisioning); services that affect climate, floods, disease, wastes and water quality (regulating); services that provide recreational, aesthetic and spiritual benefits (cultural). The human species, while buffered against environmental changes by culture and technology, is fundamentally dependent on the flow of ecosystem services."

Adapted from (45) following the Common International Classification of Ecosystem Services (CICES) categorization (46)

Because agricultural biodiversity has co-evolved with farming systems and breeding systems, it is already deeply integrated within these systems. Increasing what we know about agricultural biodiversity, its components and the interactions among them can help countries to leverage their existing resources and knowledge for integrated nutrition and environmental outcomes.

Agricultural biodiversity is, however, under threat. Despite the many benefits it provides, agricultural biodiversity is being lost as:

- Farming production systems have shifted to more intensive production practices which rely on fewer varieties, genes or species (10, 31, 47, 48)
- Traditional agricultural practices and knowledge are displaced (by intensive, external input-based management practices) and undervalued
- Climate change and land-use changes accelerate land degradation
- Value chains are under pressure to provide standard products year round in any country and any season.

Conservation approaches have been developed to stem biodiversity loss (Chapter 5) and seed systems strengthened to make sure that biodiversity is not only conserved, but also available and accessible when and where it is needed by those who need it for different purposes (Chapter 4).

"At the World Health Organization, we are aware of the growing body of evidence that biodiversity loss is happening at unprecedented rates. There is increasing recognition that this is a fundamental risk to the healthy and stable ecosystems that sustain all aspects of our societies."

Dr Maria Neira, Director, Public Health, Environmental & Social Determinants of Health (49)

Using agricultural biodiversity in sustainable food systems

'Sustainable food systems' are a relatively recent concept with various definitions. In July 2014, the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security of the Food and Agriculture Organization of the UN (FAO) defined a sustainable food systems as "a food system that delivers food security and nutrition for all in such a way that the economic, social and environmental bases to generate food security and nutrition for future generations are not compromised" (50).

'Using agricultural biodiversity' is the act of intentionally taking advantage of the variety and variability of plants, animals, landscapes and even soil organisms, to achieve certain goals. Using agricultural biodiversity can take many forms. It can mean identifying which plant species or varieties contain important traits, such as salinity resistance or nutrient density, and using them to breed new varieties. At the farm level, it can refer to farming practices in which genetically distinct varieties of the same species are planted together as a mixture to increase resistance to diseases, or planting different varieties in different areas of the same farm to respond to different micro-environments. It can mean planting certain varieties of a crop because they have particular nutritional or cooking qualities. Using agricultural biodiversity might entail integrated farming systems where animals, crops and trees interact, with benefits of increased yields, lower fertilizer requirements and more food groups available for healthy diets. It can also involve adopting certain farming practices such as intercropping or crop rotations, which promote beneficial interactions among species, like the *milpa* system in Central America where beans are planted together with maize and squash, an ancient agricultural method which combines crops that are nutritionally and environmentally complementary.

At a landscape level, using agricultural biodiversity refers to creating a mosaic of different land uses – managed forest, cultivated fields, waterways, hedges and copses – to create beneficial synergies, such as water capture, pest control or pollinator habitat. It often involves matching land use to land form and soil type in order to tailor production to land capability, and in so doing reduce land degradation such as soil erosion. At the same time, diversity in the landscape can ensure that different food groups (vegetables, tree fruit, animals, staples) are produced all year round. Using agricultural biodiversity draws on the local agroecological knowledge of women and men, embodied in the development and use of certain varieties, species and landscape patterns, together with the scientific knowledge of biologists, ecologists, zoologists and agronomists, among others, to create innovation. Using agricultural biodiversity often means a focus on locally specific species, breeds and varieties, which are not well known on a global scale and are under-represented in formal research (neglected and underutilized species), because of the variety and variability that they represent in a system, and their suitability to local environmental conditions and cultural requirements.

Using agricultural biodiversity can contribute to many vital aspects of a sustainable food system, in turn contributing to realization of several interconnected Sustainable Development Goals and Aichi Biodiversity Targets (Figure 1.4).

Kyanika women's group cooking traditional food, Kitui, Kenya.
Credit: Bioversity International/P.Sands

FIGURE 1.4 – Agricultural biodiversity contributes to many aspects of a sustainable food system, in turn contributing to realization of Aichi Biodiversity Targets and Sustainable Development Goals

Credit: Bioversity International/P.Gallo/A.Del Castello

Mainstreaming agricultural biodiversity in sustainable food systems

Knowledge of the value of using agricultural biodiversity is a useful first step towards food system sustainability, but to have impact, practices need to be 'mainstreamed' into other sectors.

Under the Convention on Biological Diversity, mainstreaming biodiversity is defined as: "the integration of the conservation and sustainable use of biodiversity in cross-sectoral plans such as poverty reduction, sustainable development, climate change adaptation/mitigation, trade and international cooperation, as well as in sector-specific plans such as agriculture, fisheries, forestry, mining, energy, tourism, transport and others." (51)

In practice, mainstreaming means that specific components of biodiversity (e.g. genetic, varietal, species, landscape) are integrated into other sectors for the generation of mutual benefits. Examples are: linking tourism to biodiversity for conservation and economic returns; or using diversity in agriculture to increase productivity and resilience while at the same time conserving biodiversity. Integration may be into the plans, policies and practices of natural resource sectors, such as agriculture or forestry, or other economic and social sectors, such as poverty alleviation or climate adaptation. Methods can comprise changes in policies, plans or laws, public–private partnerships or communication campaigns (See Table 1.1).

TABLE 1.1 – A framework for mainstreaming biodiversity

Integrating biodiversity…		
Integrate the components of biodiversity in order to achieve specific biodiversity goals…	**Specific components of biodiversity:** • Genetic diversity • Species and their habitats • Populations and communities • Ecological processes, functions • Landscapes, ecosystems • Ecosystem goods and services	**For specific goals:** • Minimize or mitigate risk • Restore, improve or maintain ecological integrity • Ensure ecological resilience and adaptation • Maintain ecosystem services • Improve diet diversity year round
…into sectoral plans and policies…		
…into the plans, policies and practices of natural resource sectors, and economic/social development sectors at all levels…	**Natural resource sectors:** • Agriculture • Forestry • Fisheries, aquaculture, marine • Freshwater, rivers • Grazing, grassland	**Economic and social development sectors:** • Poverty alleviation • Health • Climate adaptation • Private businesses • Food and water security • Financial investments
…using a variety of methods		
…through approaches that rely on changes in policies and plans, on economic instruments and on education, among other methods.	**Policy and plans:** • Reform or create policies, plans, laws • Create protected areas, buffer zones, corridors • Modify management plans and practices • Incorporate into strategic environmental assessments • Incorporate into spatial and land-use planning • Public–private partnerships • Market-based certification • Voluntary best practice	**Economic instruments, education, incentives, partnerships:** • Economic valuation • Payments for ecosystem services • Communication, education • Biodiversity offsets

Adapted from (52)

Mainstreaming agricultural biodiversity in food systems contributes to their sustainability and enables policymakers to make progress toward their commitments to the Sustainable Development Goals and the Aichi Biodiversity Targets. Governments make a difference through the food and agricultural policies they adopt. Corporations make a difference through the business models they select. Given the right policy environment, together with appropriate management actions and information, from the same starting point, different results are possible (Box 1.4). Policies and actions matter.

BOX 1.4 – Illustration of the effects of policies and institutional arrangements on outcomes

An analysis of the nexus between food security and biodiversity conservation in two distinct agricultural systems in the same geographical area in Brazil (Mato Grosso) noted that the interplay between institutions and policies from household to global scale resulted in one system with a monoculture of soybean and both low food security and low biodiversity; the other with a vibrant patchwork of family farms with various land-use types, and higher food security and biodiversity.

Although the two landscapes shared the same climate conditions, regional and national governments and regulatory frameworks, what made a difference was how these interacted with global, landscape and household institutions. The interactions between different sets of policies and social institutions at different scales allowed the two different outcomes to emerge. At the global level, in the monoculture case, the forces of commodity markets and rise of meat and biofuels predominated; in the family farms, it was demand for sustainably produced and socially equitable foods. At a regional level, for the monoculture, policy drivers were public financing for export commodity production (e.g. land, credit, subsidies); for the family farms, main drivers were Brazil's 'Zero Hunger' policies and investment in family farming (e.g. credit and market access). At the landscape level, monocultures were shaped by a concentration of wealth among a few producers; the family farms were shaped by marketing cooperatives, access to inputs and local market development. Finally, institutional drivers at a household level for the monoculture were access to chemical inputs and markets, and increased household income; for the family farms, they were access to inputs, access to knowledge and more stable household incomes.

The case study highlights how the interplay of multiple scale policies and management actions can influence biodiversity and food security outcomes.

 (53)

Challenges of mainstreaming agricultural biodiversity

While the potential benefits are multiple, mainstreaming agricultural biodiversity in food systems is easier said than done.

First, using agricultural biodiversity is not a 'one size fits all' solution. On the contrary, it is complex. It is about the diversity of varieties, species and systems, and how to manage such a range of options for multiple objectives – income generation, nutrition, sustainable natural resources and risk mitigation. Mainstreaming agricultural biodiversity therefore requires a systems approach, which recognizes the connectivity among elements, multiple viewpoints and the multi-functionality of food systems.

Second, there is a clear tension between specialization for increasing productivity, cost-efficiency and reaching economies of scale, and diversification for risk mitigation and stability (Box 1.4). Specialization, with intensified production geared towards local, national or international markets, can foster transitions out of poverty and boost local economic development. But important trade-offs may exist in terms of livelihood security, gender equity and landscape resilience. For example, what has been called the 'curse of the cash crops' (54) points to how specialization in high-value crops for sale (which has long been a major development strategy) can lead to negative effects on food and nutrition security, thereby limiting sustainable pathways out of poverty (54–57). In contrast, livelihood and landscape diversification help minimize production and commercial risks, and smooth out income flows throughout the year (58). Crop diversification has been found to decrease the likelihood of falling into or remaining in poverty (3). Balancing the continuum between diversification and specialization is a critical consideration in livelihoods and landscape development.

Third, mainstreaming diversity across the food system requires new ways of cross-sectoral working. While an increasing number of government and private sector departments are embracing multidisciplinary approaches (e.g. Mexico, see page 15), the successful coordination and implementation of such efforts remains a challenge. Sector accountability and reward lines may not favour them working together and there may be competition among sectors for influence and resources.

Additionally, the way different sectors approach problems may be incompatible. For example, nutritionists generally are trained in a clinical tradition, and nutrition is often housed with the Ministry of Health, so a purely health focus will lack integration with agriculture and tend to overlook the role of food diversity and agricultural biodiversity in combatting malnutrition. Another example is the jurisdiction between Ministries of Agriculture and Environment (and sometimes Forestry) for lands falling under them. Different ministries will see plant diversity (such as the wild relatives of crops) in very different ways, leading to different expectations about policies and management regimes.

A fourth challenge for policymakers is current common measures of success. Success is usually measured within sector (e.g. nutrition outcomes, production outcomes or environment outcomes) without considering negative effects (or indeed positive synergies) on other sectors. In reality, policymakers have to engage in trade-offs and balancing acts among sector goals. (59, Box 1.5)

BOX 1.5 – Worked example. The wins and losses en route to zero hunger

In sub-Saharan Africa, ending hunger (Goal 2) interacts positively with several other goals – including poverty eradication (Goal 1), health promotion (Goal 3) and achieving quality education for all (Goal 4). Addressing chronic malnourishment is 'indivisible' from addressing poverty. Tackling malnourishment reinforces educational efforts because children can concentrate and perform better in school. Not addressing food security would counteract education, when the poorest children have to help provide food for the day.

Food production interacts with climate-change mitigation (Goal 13) in several ways, because agriculture represents 20–35% of total anthropogenic greenhouse-gas emissions. Climate mitigation constrains some types of food production; in particular those related to meat (methane release from livestock constitutes nearly 40% of the global agricultural sector's total emissions). Yet food production is reinforced by a stable climate. Securing food from fisheries is also reinforced by protecting the climate, because that limits ocean warming and acidification.

Finally, in some parts of sub-Saharan Africa, promoting food production can also constrain renewable-energy production (Goal 7) and terrestrial ecosystem protection (Goal 15) by competing for water and land. Conversely, limited land availability constrains agricultural production.

The difficulty is compounded by large evidence gaps on the dynamic links between elements of a food system and long-term nutrition and sustainability outcomes.

Examples of successful mainstreaming

Despite these challenges, however, mainstreaming of agricultural biodiversity (i.e. the integration of agricultural biodiversity in other sector-specific plans) can be done.

Mainstreaming agricultural biodiversity into nutrition programmes

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 Zero Hunger Strategy umbrella and strategically targeting relevant public policies and instruments that can facilitate agricultural biodiversity mainstreaming. Public policies – such as the National School Meals Programme and the Promotion of Socio-biodiversity Product Chains among several others – provide entry points for potentially improving nutrition or livelihoods with links to native agricultural biodiversity. Results include new dietary guidelines that take into account healthy diets derived from socially and environmentally sustainable food systems. The guidelines support multiple small retail channels, including those using organic and agroecological methods, and family farming. Further outcomes can be seen in the national budget for 2016–2019, which includes many objectives, targets and initiatives related to the sustainable use of biodiversity for food and nutrition (e.g. promoting biodiversity products in public purchases from family farming) (60).

Mainstreaming agricultural biodiversity into agricultural production

UN Environment from 2004 to 2014 assisted 47 countries in Africa, Asia and Latin America to mainstream agricultural biodiversity conservation and sustainable use in the agriculture production sector. The projects were implemented in biodiversity-rich areas with globally significant agricultural ecosystems and where agricultural biodiversity is central to the livelihood strategies of small-scale farmers, rural communities and indigenous peoples. Projects demonstrated sustainable agricultural management practices that directly contributed to the conservation and sustainable use of agricultural biodiversity on 1,254,564ha of land. As a result of the mainstreaming interventions, the governments of partner countries developed supportive strategies and policies and regulatory frameworks that address the mainstreaming of agricultural biodiversity in different ways (61). For success in integrating biodiversity in agricultural production systems, partnerships and community engagement have been found to be fundamental (62). Partnerships need to be between different institutions (e.g. private sector, research, national governments) and between different disciplines (e.g. ecology, conservation, breeding, human health). Community institutions, such as farmer organizations and women's associations, make sure that actions reflect local needs and are grounded in local context (62).

Mainstreaming conservation of agricultural biodiversity across sectors of national government

Mexico is a federal republic and most biodiversity issues are federal matters with regulations generated at the federal level but implemented and managed by the state and local governments. The Secretariat of Environment and Natural Resources is responsible for the conservation and sustainable use of biodiversity. The Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA) has functions which influence the conservation of biodiversity at three levels: ecosystem, species and genetic diversity. To mainstream biodiversity into cross-sectoral policies, interdepartmental and crosscutting commissions for biodiversity and sustainable development were put into action with mostly different functions: one agency, the National Commission for Knowledge and Use of Biodiversity (CONABIO) charged with information and knowledge generation; one commission, chaired by the Head of SAGARPA and including representatives of the Secretaries of State to coordinate rural development interagency participation from the whole country and boost concurrent regional projects for rural development; and the third, a large, broad-based Mexican Council for Sustainable Rural Development, with representatives from most national sectors (including rural, agriculture and social) and private sectors, as well as academia and NGOs, charged with an advisory role to the federal government. These structures provide an important opportunity to internalize the value of the natural capital of Mexico in all activities of the public sector and of society at large (63).

Picking *Garcinia indica* from trees in the forest near a village of the Western Ghats, India. *G. indica* has a distinctive flavour and medicinal properties. Its dried rind is used as a flavouring agent, while the seeds are a rich source of an edible fat. As a wild tree, it has no need of irrigation, pesticides or fertilizers. Of the 35 species of *Garcinia* reported in India, seven are endemic to the Western Ghats region. However, unsustainable harvesting is common and causing rapid erosion of valuable types.
Credit: Bioversity International/E.Hermanowicz

The Agrobiodiversity Index

Governments, businesses and investors seeking to drive food system practices and policies towards sustainability need a way to visualize the links between different elements of a food system at various scales and time frames, in order to make decisions on ways to sustainably achieve nutrition and environmental goals. Bioversity International, with a wide range of partners, is developing an 'Agrobiodiversity Index' to help policymakers and other interested parties to assess dimensions of agricultural biodiversity in order to guide interventions and investments for food systems that are sustainable and nutritious. The Index will:

- Be actionable, helping different stakeholders understand where best to intervene for multiple outcomes, along a desired pathway towards sustainability
- Simplify complexity, guiding policymakers to balance long- and short-term goals in situations of multiple sectors and multiple stakeholders in order to see promising intervention points for sustainable and healthy outcomes
- Integrate multiple disciplines and sectors, and the needs of different stakeholders from farmers to economists, nutritionists and social development practitioners
- Be based on scientific principles and evidence to make sure that analyses are as robust and rigorous as possible
- Be subject to iterative improvements based on review, user feedback and scientific advancements.

This book outlines the proposed dimensions of the composite Agrobiodiversity Index:

- Healthy, diverse diets
- Sustainable farming systems
- Diversity-supplying seed systems
- Conservation of agricultural biodiversity

Each dimension represents well-researched systems in their own right – nutrition systems, production systems, seed systems and conservation systems – but which are: (1) rarely considered together and (2) often not considered in terms of the multiple roles of agricultural biodiversity. Agricultural biodiversity can be a potent way to link these systems and leverage synergies among them.

The first two dimensions address one key aspect of a sustainable food system: how to integrate issues of consumption and production. We take these as the starting point of this book. From the consumption side, our interest is in when and how agricultural biodiversity can contribute to attaining healthy and diverse diets, which provide the basis for good nutrition status. From the production side, the focus is on the role of agricultural biodiversity in supporting production systems that provide not only high yields, but also multiple benefits, such as cultural values, environmental integrity and human welfare (64). We also explore components, such as on-farm biodiversity, which can be sources simultaneously of healthy, diverse diets and multifunctional farming systems, not to mention often supporting sociocultural identity and heritage.

To support the coupled needs of diets and farming systems, agricultural biodiversity has to be made available and accessible to potential users and adequately conserved. From this, emerge the third and fourth dimensions of the Index: diversity-supplying seed systems and conservation of agricultural biodiversity. Seed systems address issues of how seeds and other planting materials get to where they are needed to support nutritious, healthy diets and multifunctional production landscapes in sufficient quantity, quality and diversity. For conservation, the focus is on what diversity needs to be conserved to support sustainable food systems, how and where it should be conserved, and who needs to play a role in conserving it.

The authors of the book take the country as the main unit of analysis.[ii] However, the vision of the Agrobiodiversity Index is that it be designed with the flexibility to be tailored to the needs of other stakeholders (such as the financial sector, businesses or companies) at different scales and levels.

Each of the following four chapters outlines evidence of the role of agricultural biodiversity in one dimension of the Index, and any existing evidence gaps that need to be filled. The intention is to draw on a wide range of literature to present the core ideas around each dimension rather than conduct and present a systematic review or meta-analysis. Given the different nature of each dimension, each chapter focuses on different components and scales of agricultural biodiversity (Table 1.2).

TABLE 1.2 – Summary of components of agricultural biodiversity covered in each chapter

Chapter focus	Components of agricultural biodiversity addressed	Key areas to consider
Healthy, diverse diets	All diversity used for food – cultivated plants, domesticated animals, aquatic species and foods from the wild. Both among-species and within-species diversity	Nutritional composition of food biodiversity Food biodiversity on farm Food biodiversity in the wild Food biodiversity in markets Market diversity
Multiple benefits from sustainable farming systems	The diversity among and within cultivated plants, and their interactions with other elements of biodiversity (e.g. pollinators, soil fauna), including interactions between cultivated and wild biodiversity. Levels of diversity from genetic and species to farm and ecosystem	Agricultural biodiversity and… - Soil erosion control - Pest and disease control - Pollination - Wild biodiversity conservation - Soil quality - Yield of crops for food - Resilient agricultural landscapes
Diversity-supplying seed systems	Crop and food tree diversity, among and within species	Seed access Seed production and distribution Seed innovation Seed regulation
Conservation of agricultural biodiversity	The major components of farming systems for food – food crops and their many varieties, and domesticated animals. Both among-species and within-species diversity	On-farm conservation *In situ* conservation in the wild *Ex situ* conservation

The authors lay out the evidence for the role of agricultural biodiversity in each dimension and describe evidence of key areas to consider. They also reflect on how to assess and track each of these essential areas, proposing a set of candidate indicators for the Agrobiodiversity Index, selected through application of the criteria developed by the Biodiversity Indicators Partnership (BIP) (65): [iii]

- Scientifically valid: (a) there is an accepted theory of the relationship between the indicator and its purpose, with agreement that change in the indicator does indicate change in the issue of concern; (b) the data used is reliable and verifiable
- Based on available data so that the indicator can be produced regularly over time
- Responsive to change in the issue of interest
- Easily understandable: (a) conceptually, how the measure relates to the purpose, (b) in its presentation, and (c) the interpretation of the data
- Relevant to users' needs
- 'Championed' by an institution responsible for the indicator's continued production and communication
- Used: for measuring progress, early warning of problems, understanding an issue, reporting, awareness raising, etc.

The final chapter draws on the evidence presented to propose a framework for the Agrobiodiversity Index and compile a first set of candidate indicators for discussion with stakeholders. This chapter outlines the processes and inputs, including stakeholder conversations, analyses and indicator refinement, followed to develop this cost-efficient, robust and usable tool for all those seeking increased food system sustainability.

Conclusions

"…we highlight the close link between climate change, sustainable agriculture and food and nutrition security with the message that 'The climate is changing. Food and agriculture must too.' Without concerted action, millions more people could fall into poverty and hunger, threatening to reverse hard-won gains and placing in jeopardy our ability to achieve the Sustainable Development Goals."

Ban Ki-moon, World Food Day statement, October 2016

It is imperative for the world to change practices to get on a more sustainable route. The 2030 Agenda for Sustainable Development recognizes this necessity and suggests integrated targets which bring together indivisible goals of economic, social and environmental progress. To tackle these, new approaches are needed. In the context of sustainable food systems – which deliver food security and nutrition for all in such a way that the economic, social and environmental bases to generate food security and nutrition for future generations are not compromised – agricultural biodiversity is a key resource. While agricultural biodiversity alone is not the sum and breadth of a sustainable food system – many other elements are needed, such as sustainable agronomic practices and socially just working conditions for agricultural workers – it is also true that it is impossible to have a sustainable food system without agricultural biodiversity, since it represents the foundations of agriculture.

Although there have been calls now for over a decade to mainstream biodiversity into nutrition, farming and forestry, policymakers often find it difficult to identify what that means in practice and how to intervene. Many indicators exist for individually or separately measuring biodiversity conservation, production system effectiveness, ecosystem health and human nutrition (66). The Agrobiodiversity Index is being developed as a tool for integrating an evidence-based selection of these indicators into one composite index which offers visualization and assessment across multiple aspects of a sustainable food system. No other index exists which integrates agricultural biodiversity issues across genetic resource management, production and consumption in food systems. It will combine large-scale quantitative data sources, with granular crowdsourced data, qualitative insights and assessments of policies and programmes in order to identify leverage points for action. The Agrobiodiversity Index will be designed to be flexible to the needs of different users. It will help countries to track progress towards several Sustainable Development Goals and Aichi Biodiversity Targets. It will also be designed for companies and for public and private investors interested in more sustainable practices in business and finance. The index can also provide information to farmer and consumer associations, to inform their decisions about sustainable practices or as a basis for a call to collective action.

Notes

[i] The Convention on Biological Diversity is one of three 'Rio Conventions' along with the United Nations Convention to Combat Desertification and the United Nations Framework Convention on Climate Change. The three conventions derive directly from the 1992 Earth Summit. Each instrument represents a way of contributing to the Sustainable Development Goals of Agenda 21 (the action plan of the United Nations with regard to sustainable development). The three conventions are intrinsically linked, operating in the same ecosystems and addressing interdependent issues. While not addressed directly in this book, agricultural biodiversity is also a component of efforts to combat desertification and tackle climate change challenges (through both mitigation and adaptation). See www.cbd.int/rio/

[ii] We recognize that environmental and agricultural issues are rarely confined to national borders – species populations can span many countries, environmental problems do not respect country borders, and countries are interdependent when it comes to sharing genetic resources. Furthermore differences in country size – e.g. between China and Costa Rica – can make country comparisons challenging. However, since most policy is taken at national level, we have selected this as the best unit for interventions.

[iii] The Biodiversity Indicators Partnership is a global initiative to promote and coordinate the development and delivery of biodiversity indicators for use by the Convention on Biological Diversity (CBD) and other biodiversity-related conventions, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), the Sustainable Development Goals (SDGs) and national and regional agencies. The Partnership currently brings together over 50 organizations working internationally on indicator development to provide the most comprehensive information on biodiversity trends. See www.bipindicators.net/.

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Traditional Sri Lankan dishes, paired with the vegetables used.
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