SUMMARY

Mainstreaming Agrobiodiversity in Sustainable Food Systems

Scientific Foundations for an Agrobiodiversity Index

AGROBIODIVERSITY INDEX

Bioversity International

European Commission

This booklet presents a summary of the key messages and content from the publication *Mainstreaming Agrobiodiversity in Sustainable Food Systems: Scientific Foundations for an Agrobiodiversity Index* (to be published in 2017).

Bioversity International is a global research-for-development organization. We have a vision – that agricultural biodiversity nourishes people and sustains the planet.

We deliver scientific evidence, management practices and policy options to use and safeguard agricultural and tree biodiversity to attain sustainable global food and nutrition security. We work with partners in low-income countries in different regions where agricultural and tree biodiversity can contribute to improved nutrition, resilience, productivity and climate change adaptation.

Bioversity International is a CGIAR Research Centre. CGIAR is a global research partnership for a food-secure future.

Citation
Mainstreaming Agrobiodiversity in Sustainable Food Systems: Scientific Foundations for an Agrobiodiversity Index – Summary. Bioversity International, Rome, Italy, 2016

Cover photo
Planting rice in Nepal. Credit: Bioversity International/Sriram Subedi, LI-BIRD, Lamjung

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ISBN: 978-92-9255-059-2

Foreword

As the United Nations Decade on Biodiversity (2011-2020) reaches its mid-point, the UN Decade of Action on Nutrition has just begun (2016–2020). This 5-year overlap of global action offers a rare opportunity to bring together biodiversity and nutrition in novel ways for positive benefits to both. When people think of good nutrition, and about the diverse food groups that should be in a balanced diet, they rarely think about where those foods come from. By the same token, when people think about biological diversity, they may think about our animals, plants and birds in the wild, but they may not make the link to the amazing diversity that contributes to our food systems – the awe-inspiring diversity of species and varieties of cereals, pulses, fruits, vegetables, animals and fish – which have been developed by farmers over millennia and which are adapted to local customs and to different environments. These links between production and consumption are important to sustainable food systems in order to have the richest possible food diversity on plates, sustainably sourced from the biological diversity that underpins agricultural systems.

The Convention on Biological Diversity – with partners including Bioversity International – has spearheaded for 10 years a Cross-cutting Initiative on Biodiversity for Food and Nutrition. Much progress has been made in bridging agricultural biodiversity and nutrition in these 10 years, but more can be done to integrate these two agendas. Silo thinking still prevails in many cases, leaving nutrition practitioners and agricultural practitioners blind to the benefits of agricultural biodiversity to healthy, year-round diets and to resilient, adapted farming systems.

The Sustainable Development Goals provide a renewed impetus for a focus on using biodiversity for food and nutrition and linking that to the sustainability of farming systems. Mainstreaming biodiversity in sustainable food systems is vital if we are to achieve those Goals by 2030. Using biodiversity for sustainable farming systems that produce diverse, nutritious foods will contribute to the conservation of these precious resources; conserving biodiversity resources will make them available for future climate scenarios and today's nutrient needs.

For this reason, the creation of an Agrobiodiversity Index, which can help bring production and consumption together for sustainable biodiversity-based solutions could go a long way to raise awareness about the multiple links between biodiversity, healthy nutrition and sustainable food production, thereby promoting the multiple aspects of sustainable food systems.

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Executive Secretary
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Acknowledgments

Prototype development of the Agrobiodiversity Index is supported by the European Commission Directorate General for International Cooperation and Development.

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Preface

In a true sense we have with us a treasure of valuable agrobiodiversity that we have not explored scientifically yet.
Narendra Modi, Prime Minister of India

The following pages comprise a summary of a book on *Mainstreaming Agrobiodiversity in Sustainable Food Systems: Scientific Foundations for an Agrobiodiversity Index.* The Delhi Declaration on Agrobiodiversity Management, adopted at the first International Agrobiodiversity Congress, held in November 2016, calls for "an agrobiodiversity index to help monitor conservation and use of agrobiodiversity."

The book is the first step in the process of creating such an index, which can measure agricultural biodiversity across different dimensions. The concept grew from the observation that juxtaposing data from very different fields connected with agricultural biodiversity can yield novel and practical insights. There is a need to measure and understand biodiversity in rapid, cost-efficient ways, going beyond just numbers, to connect also with policy decisions by countries and companies on best practices to foster diversity. Expected benefits are to be able to identify and steer opportunities for change towards sustainable food systems, and to be able to better measure and manage progress towards global targets such as the Sustainable Development Goals and the Aichi Biodiversity Targets of the Convention on Biological Diversity. Private companies and finance institutions are also interested in its applicability to measure the sustainability of investments, green bonds and company purchasing policies, while farmer organizations and consumer associations can use it to influence programmes and policies.

There is no shortage of data. Indeed there is a huge, and growing, number of existing datasets related to agricultural biodiversity, collected at different scales across different dimensions. The question is how to choose which to use in the Agrobiodiversity Index in order to draw insights for action. In this book, we summarize evidence on the contribution of agricultural biodiversity to four interconnected dimensions:

- Diverse, healthy diets
- Multiple benefits in sustainable farming systems
- Seed systems delivering crop diversity for sustainable food systems
- Conserving agricultural biodiversity for use in sustainable food systems.

Within each dimension, agricultural biodiversity scientists reviewed the scientific literature to identify evidence for the most salient aspects with respect to agricultural biodiversity. These aspects provide a starting point for identifying indicators for the Agrobiodiversity Index, which will be tested and validated in the months to come. The book, which will be published early in 2017, provides an overview of evidence, which scholars and practitioners alike will find useful in our joint quest to use agricultural biodiversity in food systems that are sustainable.

M. Ann Tutwiler

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Why mainstream agricultural biodiversity in sustainable food systems?

CHAPTER 1

KEY MESSAGES:

- → **Food systems need to be reformed if they are to nourish people while taking care of 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 climate-tolerant, 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.**

Food systems need to be reformed if they are to nourish people with high quality diets and at the same time protect the environment.

The agricultural system that produces the world's food today is failing its nutritional needs. At present, one in three people in the world suffers from micronutrient deficiencies – when they lack vitamins and minerals that are essential for growth and development – and almost 2 billion people are overweight or obese (1). These forms of malnutrition often co-exist.

> *What is required is a fundamentally different model of agriculture based on diversifying farms and farming landscapes.*
>
> IPES-Food, 2016

At the same time, the agricultural system that produces the world's food is driving environmental harm. Agriculture contributes around 24% of global greenhouse gas emissions (2) and is the single largest user of fresh water on the planet (3). Sixty-two percent (5,407) of IUCN globally threatened species are affected by agriculture (4). In turn, environmental harm is threatening the agricultural system. The International Panel on Climate Change predicts that climate change will reduce agricultural production by 2%, while demand will increase by 14% every decade until 2050 (5).

Both diets and agricultural systems have been greatly simplified over the past century. While the diversity on offer on a country-by-country basis has never been higher, the global diet as a whole is becoming more homogenized with a declining intake of health-giving pulses, fruits and vegetables, and a predominance of starches, such as rice, wheat and maize, along with meat and dairy (6). The production of fruit and vegetables, nuts and seeds falls about 22% short of population need according to nutrition recommendations (7).

From the 391,000 documented plant species, 5,538 have been counted as human food (8). Out of these, just three – rice, wheat and maize – provide more than 50% of the world's plant-derived calories (9). Relying so heavily on such a narrow resource base is a risky strategy for the planet, for individual livelihoods and for nutritious diets.

The Sustainable Development Goals (SDGs), signed by all 193 countries in 2015, compel a new approach if we are to transform our world by 2030. They join the Aichi Biodiversity Targets of the Convention on Biological Diversity (2010) as key frameworks for sustainable development. Sustainability means recognizing that economic, environmental and social concerns are all fundamentally connected. Addressing them in a disconnected way will lead to long-term failure: we cannot nourish the world population and alleviate poverty, if the price is a degraded environment that cannot sustain the next generation. We cannot protect the environment for future generations at the expense of people who need nutritious foods today.

The good news is that sustainable solutions are possible.

Two major reports issued in 2016 highlight what is needed. The Global Panel on Agriculture and Food Systems for Nutrition lists poor diets as the world's number one health risk (27%) (10). It calls for governments to build sustainability into each country's agricultural system while producing diets that are high quality from a nutritional perspective. The International Panel of Experts on Sustainable Food Systems identifies the shift needed for that to be possible – from uniformity to diversity of diets and agricultural systems (11).

Agricultural biodiversity – the diversity of crops and their wild relatives, trees, livestock and landscapes – 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 stress-tolerant, nutritious crops and animal breeds. Agricultural biodiversity is already a key component of farming systems and breeding systems worldwide. Increasing knowledge about it can help countries to leverage their existing resources for joint nutrition and environment outcomes.

At WHO, 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, WHO 2015

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

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.

Mainstreaming biodiversity in food systems contributes to making food systems sustainable and enables policymakers to make progress toward their commitments to the Sustainable Development Goals and the Convention on Biological Diversity Aichi Targets (Fig. 1.1).

Governments make a difference through the food and agricultural policies they adopt. Given the right policy environment, together with management actions and information, from the same starting point, different results are possible. For example, analysis of two distinct agricultural systems in the same region in Brazil noted that decisions and policies made from household to global scale resulted in one with a monoculture of soybean and both low food security and low biodiversity; the other with a vibrant patchwork of land use types, and higher food security and biodiversity (12). Policies and actions matter.

Evidence-based policymaking requires sound evidence. And yet current metrics are not up to the task (11). Current common measures of success capture only a part of the food system, for example 'yield per hectare' for agricultural production or 'calories produced' for food security. These measures rarely, if ever, take into account the effect on other sectors. There are also large evidence gaps on the dynamic links between elements of a food system and long-term nutrition and sustainability outcomes (10). Governments need a way to assess across these elements and visualize the links between them in order to make decisions on ways to improve them.

FIGURE 1.1 SELECTED ELEMENTS OF A SUSTAINABLE FOOD SYSTEM, AND HOW THEIR LINKAGES CONTRIBUTE TO THE SUS

We propose an 'Agrobiodiversity Index' to help policymakers assess dimensions of agricultural biodiversity to guide interventions and investments for sustainable and nutritious food systems. The Agrobiodiversity Index will allow the side-by-side visualization and assessment of important dimensions of a sustainable food system to identify leverage points for action:

- Healthy, diverse diets
- Multiple benefits from production systems
- Diversity-supplying seed systems
- Conservation of agricultural biodiversity.

The pages that follow outline current evidence – and evidence gaps – of the contribution of these dimensions to sustainable food systems and how they interact with biodiversity, and lay the foundations for the Agrobiodiversity Index.

TAINABLE DEVELOPMENT GOALS (SDG) AND TO AICHI TARGETS (AT)

The objectives to end hunger, achieve food security and improved nutrition, promote sustainable agriculture (SDG2) and ensure healthy lives (SDG3) depend on responsible (SDG12) and sustainable (AT4) consumption and production. The climate (SDG13) affects and is affected by agricultural and forest production practices. Sustainable production in agriculture, forestry and fisheries protects life on land (SDG15), reduces pollution (AT8), safeguards ecosystems and their essential services (AT14), and restores degraded ecosystems and resilience (AT15), ensuring conservation of biodiversity (AT7). Healthy ecosystems are underpinned by genetic diversity (AT13, SDG Target 2.5), which, in turn, contributes back to food and nutrition security. Genetic diversity is maintained also in wild relatives of domesticated animals and crops in protected areas (AT11).

Across all elements and their linkages, scientific knowledge relating to biodiversity, its values, functioning, status and trends, and the consequences of its loss, needs to be improved, shared and applied (AT19), and included in national biodiversity strategies and action plans (AT17).

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Agricultural biodiversity for healthy, diverse diets

CHAPTER 2

KEY MESSAGES:

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

Healthy diets and food biodiversity

One of the world's greatest challenges is to secure universal access to sufficient, healthy and affordable food that is produced sustainably (1). Almost two billion people are overweight or obese, while two billion lack essential vitamins and minerals needed for adequate nutrition (2). The quantity and quality of foods produced in our fields or collected from the wild (3) and the availability, affordability, convenience and desirability of food in markets, have a direct impact on the quality of our diet (4).

There is no one-size-fits-all definition of a healthy diet as individual and cultural factors need to be considered. However, the general components of a healthy diet as defined by the World Health Organization include fruits, vegetables, legumes, nuts and whole grains (5). These essential elements are provided through food biodiversity, or the diversity of plants, animals and other organisms used for food, covering the genetic resources within species, between species and provided by ecosystems, both cultivated and from the wild.

Food-based dietary guidelines around the world recommend a diverse diet. A diverse diet increases the likelihood of consuming adequate amounts of the full range of food components essential to human health (6). The greatest opportunities to improve nutrition with food biodiversity are to employ food-based approaches that focus on the quality of the whole diet all year round.

The nutritional value of food biodiversity

Food composition studies demonstrate that there can be important differences in nutrient content both between species and within species. This knowledge can be used to select and promote the most nutrient-dense species, varieties and breeds for production systems and markets.

The nutrient composition of numerous wild and indigenous species is higher for many nutrients compared to their more widely cultivated counterparts. This has been documented for indigenous fruits (7, 8), indigenous leafy vegetables (9), and indigenous small fish (10). In Bangladesh, for example, indigenous fish, such as chapila, chela, darkina, mola and rani, contain more than the recommended daily allowance of B12 for pregnant women and children, compared to less than 20% for tilapia and carp (11). There can also be dramatic differences within species (12). For example, 200g of rice per day can represent less than 25% or more than 65% of the recommended daily intake of protein, depending on the variety consumed (13). The widely consumed Cavendish banana cultivar contains almost no carotenoids,[1] while banana cultivars indigenous to the Pacific Islands, such as Karat, Utin Lap and Utimwas, contain several hundred micrograms of carotenoids (14). Significant nutrient content differences in meat and milk among different breeds of the same animal species have also been documented (15–17).

Meal prepared by local nutritionists in Busia, Kenya. The brown ugali is made of cassava and sorghum. The meal contains oil, onion, tomato and a mix of traditional plants (jute mallow, cowpea and pumpkin leaves and amaranth). Cassava is drought tolerant. A balanced dish such as this provides a good source of protein (egg), carbohydrates (brown ugali), fats (vegetable oil), vitamins and minerals (vegetables, ugali, watermelon and egg). Credit: Bioversity International/A.Grasso

Getting food biodiversity to consumers

Food biodiversity reaches consumers through two principal pathways: [1] consumption via own production or gathering from the wild, and [2] purchase of wild or cultivated biodiversity.

Keeping a range of food biodiversity available in farms, the wild and markets can smooth seasonal fluctuations in nutrient-dense foods, provide nutrient-rich choices during times of shortage, and, perhaps most importantly, diversify the range of healthy food choices for consumers.

Food biodiversity from own production or the wild

While the interactions between food biodiversity, diet diversity and nutrition are a relatively new area of study, two recent reviews look specifically into these relationships. One found that in four out of five studies the relationship between total crop diversity and individual or household dietary diversity measured across food groups was positive (3). A review of the relationship between household-level food biodiversity and household or individual-level dietary diversity or quality also found a positive correlation in 14 out of 15 studies (18).[2] These associations were independent of household wealth or market access.

'Nutrition-sensitive' agricultural interventions use food-based strategies to modify diets. Typical strategies include home gardening, aquaculture and small-scale fisheries, small livestock rearing, and dairy development programmes, as well as strategies to improve food processing, storage and preparation (19). Nutrition knowledge is key – strategies that are accompanied by a nutrition education component are more successful (20, 21). Although rarely targeted explicitly at dietary diversification, many of these strategies have the potential to diversify diets by promoting production of, and access to, a wider variety of foods. Reviews of food-based agricultural interventions (20–22) have concluded that food-based strategies can result in improvements in dietary diversity.

Homestead food production in particular has been found to have a positive impact on nutritious diets. For example, a review of homestead production in four countries in Asia concluded that increasing the number of varieties of micronutrient-rich fruits and vegetables and animal-source foods available year round was one pathway that led to increased consumption of micronutrient-rich foods and improved micronutrient status (23).

Food biodiversity purchased in markets

Purchased food is a second pathway for improving dietary diversity, complementing the first for those who grow and gather food biodiversity or as an exclusive pathway for those who do not. For market-based approaches to be successful, food biodiversity must be accessible, available, affordable and acceptable. For example, in Benin, better **access** to markets was linked with higher availability of on-farm biodiversity and facilitated the purchase and sales of food biodiversity, contributing to diet diversity of mothers (24). **Affordability** is key for low-income groups, which figure prominently among malnourished populations, as moving towards healthier diets comes at a price. In rural South Africa, for instance, a typical household would need to increase food expenditures by more than 30% of total income to eat a healthier diet (25).

Acceptability is linked to perceptions of taste, palatability, prestige, convenience and cultural factors, among others. There has been a striking shift towards increased demand for convenience, often highly processed, foods. In East and Southern Africa, the market share of such foods has risen to one-third of the purchased food market, with little differentiation between rural and urban areas (31% vs 35%) (26). Acceptability of food biodiversity can be shaped by awareness-raising, education and capacity building. For example, 45.2% of households in Kenya which had participated in awareness-raising activities about the nutrient content of some 40 different species of traditional leafy vegetables still reported an increase in consumption 10 years later (27). In general, leveraging markets for increased production and consumption of food biodiversity requires strong cross-sectoral collaboration to improve affordability through increased efficiencies in agri-food value chains and acceptability through promotional campaigns and education.

Enabling environment

Reshaping current food and agriculture policies and investments – which often focus on maximizing productivity with little consideration of how to improve food and diet quality – through diversification of biodiversity in production systems and markets will require multiple actions at multiple scales. Greater investment in agricultural research is key to make a wider diversity of fruits, vegetables, pulses, nuts and seeds and other healthy foods available and more affordable to consumers (28).

Brazil has recently adapted several of its policies to include promotion of local and indigenous biodiversity for food and nutrition, which can provide examples to other countries. Actions taken in Brazil include promoting diverse, healthy native foods in dietary guidelines, supporting production of food biodiversity through public procurement strategies (e.g. for foods in schools), and prioritizing food biodiversity in relevant national strategies/action plans and agriculture and nutrition policies (29). Supporting positive perceptions and norms regarding biodiverse diets, for example by celebrating food biodiversity at events such as the Alaçatı Herb Festival and the Urla Artichoke Festival in Turkey (30) and collaborations with celebrity chefs, are another means to create an enabling environment with consumers. Finally, the various facets of producing and consuming food biodiversity can be integrated into the curricula of schools, universities and other educational institutions for broader action and uptake (29).

Notes

[1] Carotenoids are important antioxidants and precursor to vitamin A.

[2] Five of the studies are included in both the Powell and the Jones review. Due to the nature of the evidence reported, it is not possible to separate the conclusions from each other.

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

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Using agricultural biodiversity to provide multiple benefits in sustainable farming systems

CHAPTER 3

KEY MESSAGES:

- → **Managing farming systems sustainably means that agriculture needs to be about much more than yields of commodity crops in highly simplified and specialized landscapes.**
- → **Agricultural biodiversity provides variety and variability within and among species, fields and landscapes. This diversity helps drive critical ecological processes (e.g. soil structure maintenance) and allows a landscape to simultaneously provide multiple benefits to people (e.g. nutritious foods, income, natural pest control, pollination, water quality).**
- → **Agricultural biodiversity is used by rural communities worldwide in many time-tested practices that can confer increased resilience to farms, communities and landscapes; using it more effectively and more sustainably can help to maintain and increase the flow of services and benefits that agricultural biodiversity provides to communities.**

Why is agricultural biodiversity important in sustainable farming systems?

Over 38% of the world's land is used for agriculture, with 11% planted with annual crops (1). With the human population projected to reach up to 11 billion by 2100 (2), and with changing consumption patterns that include more meat and dairy products, there are growing calls to produce greater quantities of food. Much of the land suitable for agriculture has already been cleared, so there is an increasingly urgent emphasis on growing more foods more intensively on land that is already used for agriculture – agricultural intensification.

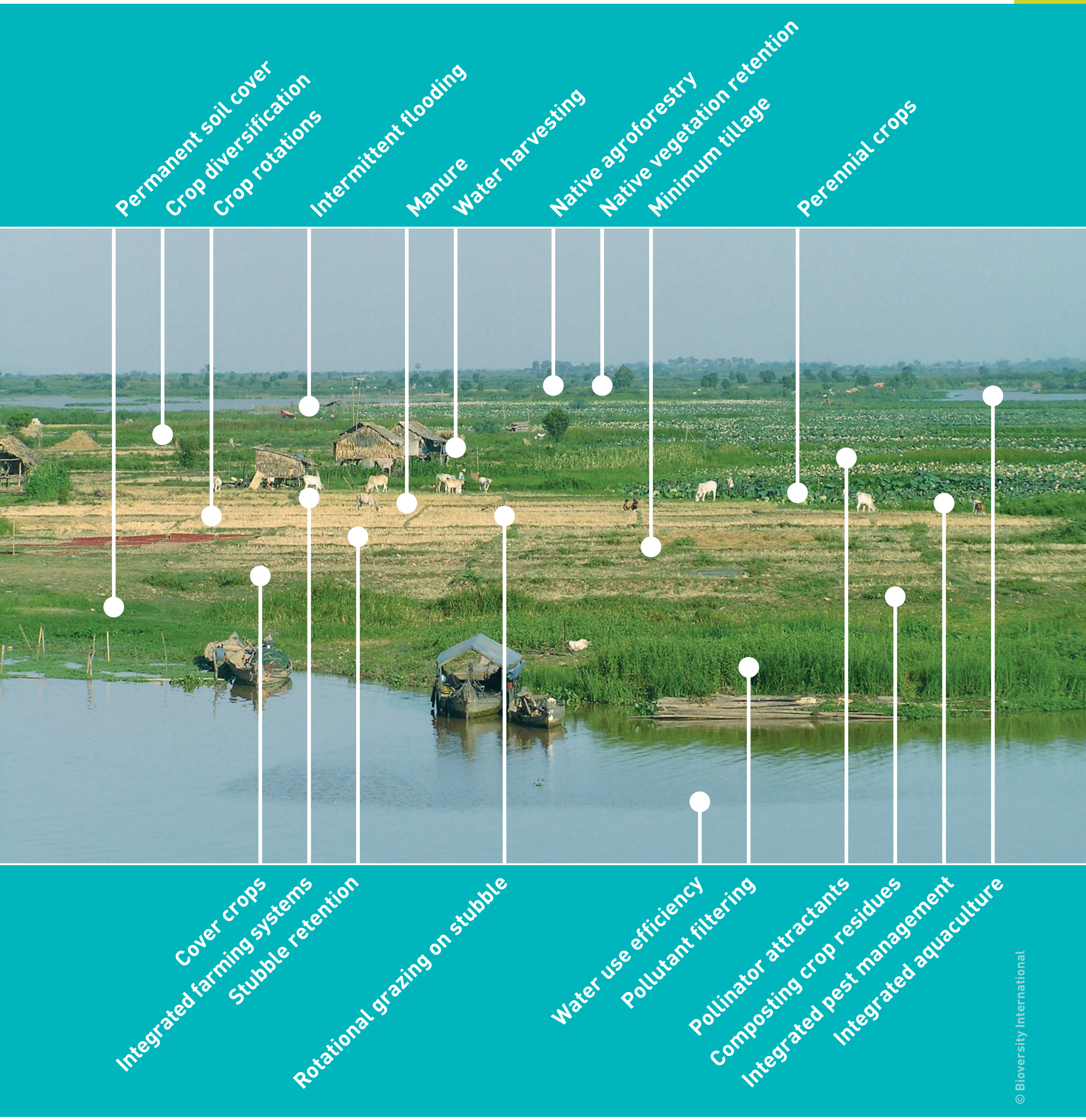
Agricultural intensification, combined with the growing homogenization of the global food system, has led to a range of negative impacts, including biodiversity loss and environmental degradation (3), decreased dietary and nutritional diversity (4) and social impacts such as increased gender inequalities (5). The simplification of the world's farming and food systems leaves farmers with a decreasing range of resources to draw on to manage threats such as the risks of crop failure due to pests and diseases, declining soil fertility, or the impacts associated with increasing climatic variability. In order to address these and many other issues, sustainable practices are needed, and agricultural biodiversity is a key component of this.

Agricultural biodiversity is a source of interacting elements of different species, varieties of species and different land uses in mosaic landscapes (fields, forest patches, waterways, etc.). These interactions, if managed using agroecological approaches and principles (e.g. intercropping, natural pest control), can lead to food grown both more intensively and more sustainably on the available land. The goal is to meet current food and nutrition needs while maintaining healthy ecosystems that can also provide food for generations to come. Besides reducing negative impacts on the environment, using agricultural biodiversity for sustainable intensification can also lead to virtuous cycles of positive impacts upon the environment and the generation of multiple services and functions (Fig. 3.1). Areas in which agricultural biodiversity can contribute to the growing push for sustainable intensification include: increasing productivity, yield, stability, pollination, pest and disease control, various aspects of soil function, wild biodiversity conservation and climate resilience. It can also substitute for many external inputs such as inorganic fertilizers and synthetic pesticides (6).

Agricultural biodiversity in farming systems contributes in an integrated way to several global goals and targets at once, including Sustainable Development Goals 2 (Zero hunger), 12 (Responsible production and consumption) and 15 (Life on land), and Aichi Biodiversity Targets 7 (Sustainable agriculture), 13 (Genetic diversity maintained) and 14 (Ecosystems and essential services safeguarded).

FIGURE 3.1 AGRICULTURAL BIODIVERSITY IS USED FOR SUSTAINABLE INTENSIFICATION

Examples of how different land and water uses can be integrated (e.g. grazing rice paddy stubble, integrating aquaculture into water bodies), as well as combining semi-natural elements such as vegetated field margins into the production system in order to provide ecosystem services (e.g. pest control) from wild biodiversity. Kampong Chhnang floodplain, Cambodia. Original image © Eric Baran



Evidence of the links between agricultural biodiversity and sustainable food systems

Agricultural biodiversity's contribution to sustainable food systems can be analyzed at four scales: within species, between species, field and farm, and landscape (Fig. 3.2). Within-species diversity refers to the diversity of varieties within a species and can help deliver ecosystem services, such as reducing crop vulnerability to pests and diseases and increasing yield stability. For example, households growing higher numbers of varieties of common bean in Uganda experienced less frequent and less severe damage to crops from weevils and other pests (7).

At the species level, diversity can drive a wide range of ecosystem services, such as providing habitat and resources for pollinators and other wild biodiversity. For example, in a study examining types of insects and other invertebrates in monocropped systems compared to multispecies crops, mixed plants were found to host reduced numbers of pests (23%) and increased natural enemy abundance (44%), leading to a 54% increase in pest predation (8). At field scales, increased agricultural biodiversity (e.g. crop rotations) can lead to increased soil biological diversity, which in turn can increase nutrient status of soils. For example, a recent study found that earthworm abundance and diversity was greater in crops grown with a rotation (growing of different crops in succession on the same piece of land) than crops grown without a rotation (same crop in consecutive growing seasons) (9). Finally, at the landscape scale, agricultural biodiversity can provide ecosystem services, from pollination to human nutrition to carbon sequestration. For example, the number of developed pods in pollinator-dependent bean crops in Sweden increased with greater proportions of semi-natural vegetation in the landscape (10).

Agricultural biodiversity-based strategies are thus important for soil erosion control, climate resilience, pest and disease control, productivity, pollination and wild biodiversity conservation. Examples of strategies include:

- Soil erosion can be controlled by matching crop varieties, species or both to land and soil types, and by selecting deep-rooted crops
- Climate resilience can be addressed by using crop varieties and species that are well adapted to current or projected future climatic conditions (e.g. drought resistant)
- Integrating multiple elements of different land and water uses (e.g. cropping on land, livestock grazing, fish farming) allows recycling of waste, improved nutrient management and improved pest control, as well as diversifying diets and livelihoods
- Cropping systems that are more diverse (e.g. mixed crops, retained semi-natural habitats, heterogeneous landscapes) provide greater range of habitats for wild biodiversity than simplified and homogenous cropping systems.

Enabling Environments

Supportive social, economic and governance institutions are needed for agroecosystems to function in a manner that is socially, ecologically and economically sustainable. Institutions and incentives can play an important role in supporting the multifunctional sustainable farming systems that are needed today in order to meet a host of interacting global challenges. For instance, supporting community-based approaches (community seedbanks) and farmer-led grassroot approaches facilitates access to a wider range of new crop species and varieties and helps build social capital in communities. Incentives can also help catalyze agricultural biodiversity conservation and broadscale adoption into agricultural landscapes for long-term food and nutritional security and sustainable natural resource management.

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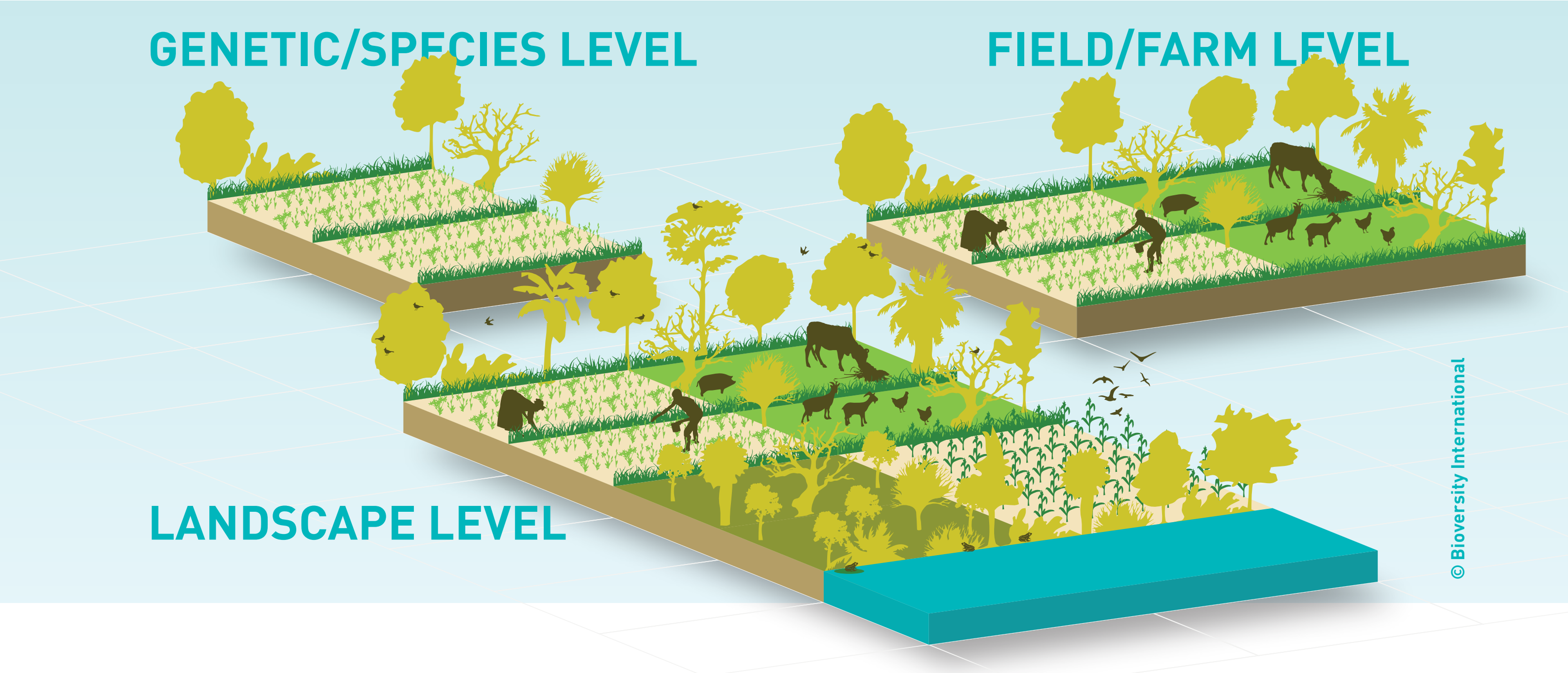
FIGURE 3.2 AGRICULTURAL BIODIVERSITY CONTRIBUTES TO HEALTHY FARMING LANDSCAPES

Crop genetic diversity allows farmers to grow different varieties to suit different environmental conditions (e.g. poor soils) and resist different weather conditions (e.g. frost, unpredictable rainfall). Planting different varieties of the same crop can decrease pest and disease damage (7) and facilitate staggered flowering times to attract diverse pollinators (11).

At farm and field level, selecting different species with different growth forms, leaf size and shape, plant heights, rooting depth and nutrient uptake strategies, provides farms with more ways to respond to disturbances and shocks (12). Integrating livestock and crops reduces the need for synthetic inputs while facilitating more efficient nutrient cycling and availability.

At landscape level, complex landscapes have multiple benefits. E.g. forest remnants can reduce pests borne by the wind, and reduce soil erosion; patches of non-cropped vegetation also support beneficial plant and insect diversity, like pest enemies and pollinators (14,15).

Farmers manage trade-offs among benefits at many scales and across all levels, e.g. more biodiversity can lead to lower greenhouse gases and better pest control, but may reduce gross yields in the short term (16–18).



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The contribution of seed systems to crop diversity for sustainable food systems

CHAPTER 4

KEY MESSAGES:

→ **The characteristics of different seed systems are crucial for sustainable food system outcomes: agricultural sustainability and healthy diets. For each of the five key functions of seed systems – facilitating access, production and distribution, innovation, regulation and conservation – there is evidence for the difference a seed system makes to sustainable food systems.**

→ **Nevertheless, currently used methods to measure the performance of seed systems concentrate narrowly on their contribution to agricultural productivity, not to food system sustainability. There is, therefore, a need to measure seed system performance in terms of their contribution to wider policy goals, moving away from current policy fragmentation.**

Seed systems and agricultural biodiversity

The diversity of crops and trees used in food production systems depends on the diversity of the planting materials that farmers use. Planting materials include seeds, seedlings, stem cuttings, roots, tubers and leaf portions. For brevity, the term 'seeds' refers to these other planting materials as well as seeds. Farmers access seeds through seed systems, which are ensembles of individuals, networks, organizations, practices and rules that provide seeds for food production. Seed systems have five key functions: [1] facilitating access to seeds, [2] seed production and distribution, [3] seed-based innovation, [4] regulation and [5] conservation of seed diversity (1, 2). These functions are at play in any type of seed system, from seed systems consisting of farmers who rely on their own seed with occasional seed exchanges with family or neighbours to a fully developed commercial seed sector (Fig 4.1).[3]

A fair number of studies and periodic monitoring tools measure seed system performance. These tend to focus on the capacity of the system to deliver modern cultivars to smallholders, with the ultimate aim of increasing agricultural productivity and farmer incomes (3, 4). For example, the Access to Seeds Index measures the efforts of the world's largest seed companies to enhance seed accessibility by smallholder farmers and to contribute to productivity increases on small farms. This index is highly informative about the performance of different seed companies in various domains, but it pays limited attention to the seed diversity being delivered by companies.

This would not be a problem if seed systems were to play only a passive role in food systems. But seed systems do not only respond to signals from other parts of the food system; they also actively drive change and play a decisive role in determining the levels of agricultural biodiversity in food production and consumption. Below is a summary of the evidence from the scientific literature of the influence that each key function of seed systems has on the capacity to deliver agricultural biodiversity to support sustainable food systems.

Seed access matters for agricultural diversification

Farmers' access to seed is determined by purchasing power, proximity of seed sources, availability of information about existing varieties, the farmers' gender, ethnic background and other cultural aspects. Public and private investments in extension services and the crops and varieties covered by these services can greatly influence the range of seeds that are eventually chosen by farmers (5).

Seed subsidies and other agricultural subsidies have an important effect on seed accessibility, and on farmers' choices about what to plant. Many financial products, such as credit and insurance, are crop-specific. Crop-specific seed and input policies often result in disincentives for farmers to cultivate other crops, including those that make important contributions to nutritious diets, such as vegetables, small grains, legumes and tubers (6).

Seed production influences seed diversity availability

The limited availability of seed in sufficient volume and diversity is often a bottleneck for agricultural diversification. It is difficult to find viable business models for seed production of crops that are mainly used for household consumption or have low profitability, as they are not commercially attractive. Often the commercial sector is limited to hybrid seeds only or staple crops, which assure better returns.

Community seedbanks can support production – often relying on barter or delayed payback in the form of grain or seeds, rather than sales (7). In Ethiopia, community seedbanks have been found to increase the number of varieties grown by participating households. Mechanisms of this kind, which stimulate the production of a broader range of landraces, can lead to better availability of seed diversity.

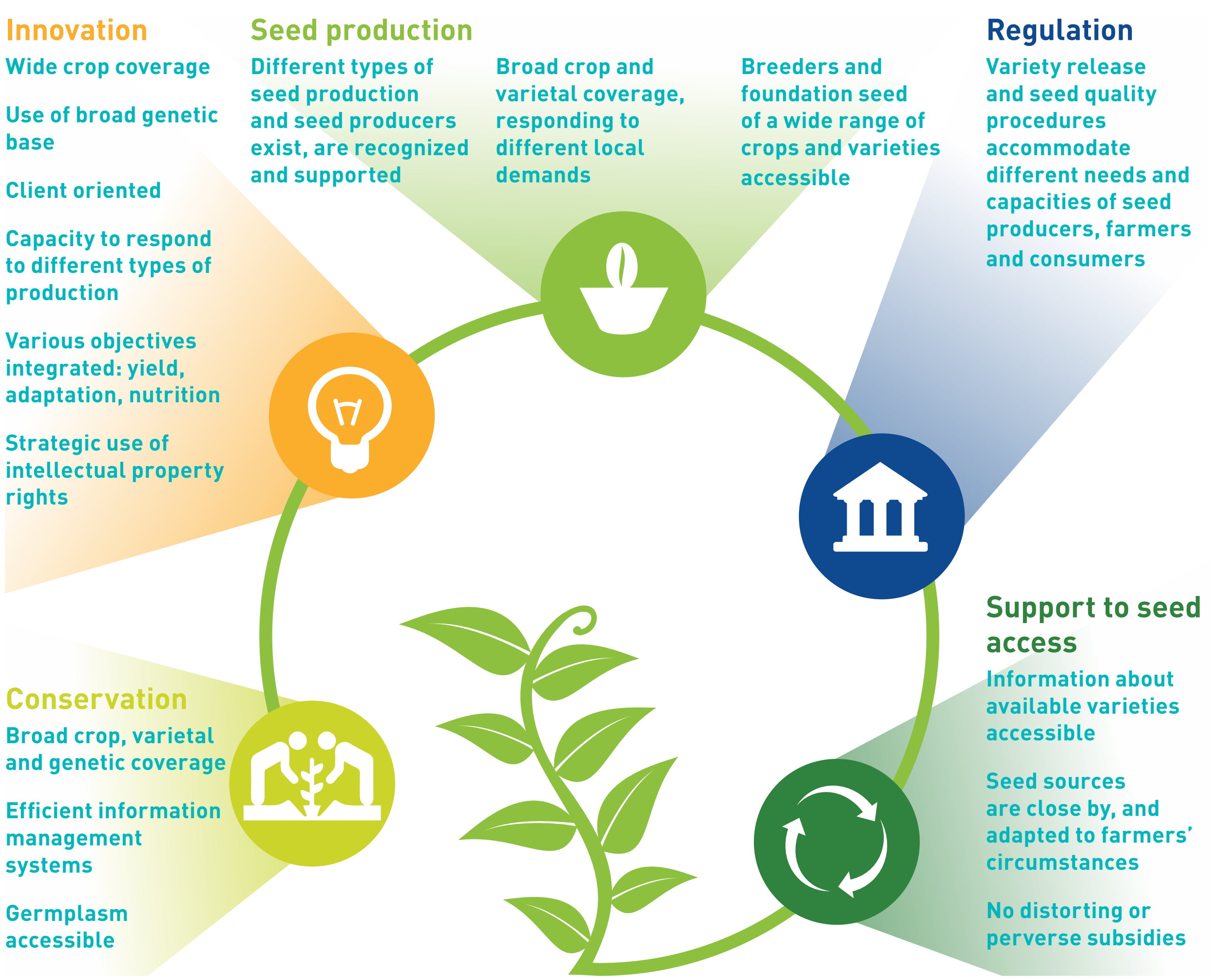
Seed innovation matters for environmental adaptation and nutrient density

The innovation function aims to select from existing genetic pools fit-for-purpose crops and varieties for use in new contexts and to generate new varieties through plant breeding.

Historically, public and private investments in formal crop breeding have concentrated on a small selection of staple crops, neglecting a wide range of species that can contribute to nutritious diets from resilient and productive farming systems, including cereal crops such as sorghum, barley and millet; legumes like beans, chickpeas, peas, pigeon peas, lentils, Bambara groundnut and vetches; roots and tubers such as sweet potatoes, yams and cassava; and food tree crops in general (8–11).

Within species, formal breeding can dramatically reduce genetic variation in target crops, with negative consequences for characteristics other than yield.

FIGURE 4.1 ELEMENTS THAT REINFORCE DIVERSITY IN THE FIVE BASIC FUNCTIONS OF SEED SYSTEMS



Innovation focusing exclusively on yield improvement has reduced considerably the nutrient density of crops. For example, a study comparing the nutrient content of 43 crops in 1950 and 1999 found a decline in the content of protein, calcium, iron, riboflavin and ascorbic acid (12). In other cases, breeding low-input, multi-resistant crops could help reduce pesticide use, but few incentives exist for input suppliers to invest in such types of innovation (13).

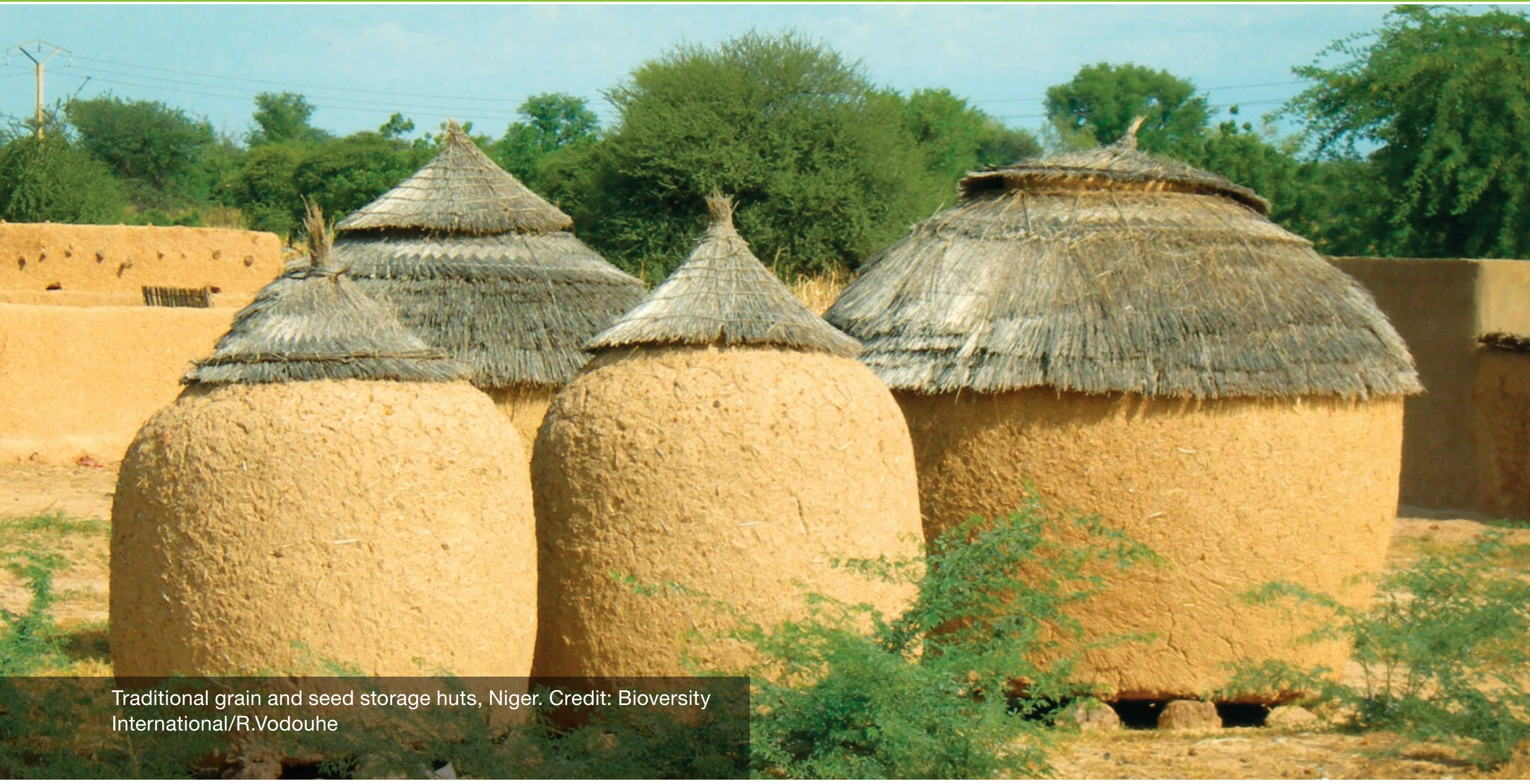
Where farmers are engaged in traditional practices for selecting, maintaining, transforming and combining varieties as food producers, sellers and consumers, selection tends to result in larger genetic pools and seed that better responds to environmental conditions and nutritional needs (14). In some cases, however, local crops can have a narrow genetic base, where they were introduced recently or where extreme biotic or abiotic stress has narrowed their genetic base for particular traits (15). In these cases, participatory plant breeding involving farmers and the food processing industry is one powerful mechanism for injecting useful crop diversity first in farmers' fields and then in consumers' diets (14).

Community-based engagement in seed innovation for sustainable food systems may be discouraged by certain intellectual property rights. For example, there may be limitations on farmers' rights to use, save, duplicate and exchange plant varieties; or a lack of recognition or compensation for farmers when new products based on their traditional varieties and ancestral knowledge are commercialized (16).

Seed policies and regulations can promote or stifle varietal diversity

For farmers it is important to know that the seed they obtain will grow into a healthy crop with expected characteristics. To ensure this, certain policies and regulations are needed, such as regulations on the market release of new crop varieties. However, very rigid control mechanisms can stifle innovation of diversity through excessive requirements on varietal testing, high costs and long procedures. Important crop varieties that perform well in particular environments sometimes cannot be registered because they do not comply with standards such as uniformity and stability (17). The rigidity of these standards represents an obstacle for landraces, local cultivars and varieties resulting from participatory plant breeding to enter the formal channels of seed production, limiting in this way their potential to contribute to sustainable and diverse food systems (5, 18).

Flexible, simplified release procedures facilitate the registration of traditional and new varieties, and seed mixtures, which can contribute to yield increases and reduced use of external inputs, in addition to increased crop diversity on farm and on consumers' plates (19, 20). For example, in Nepal, a simplified variety release procedure helped to fast-track the release or registration of new disease-tolerant varieties of mungbean, an important crop for human nutrition in this country (20).



Traditional grain and seed storage huts, Niger. Credit: Bioversity International/R.Vodouhe

Conclusions

The evidence reviewed shows that different seed systems offer varying levels of provision of agricultural biodiversity, which in turn makes an important contribution to the capacity of food systems to produce food in a sustainable way and support healthy diets. However, current methods to monitor seed systems are narrowly focused on productivity and devote little or no attention to agricultural biodiversity. This means that these monitoring systems fail to inform seed policies of their wider impact on food systems. Seed policies remain blind to their effects on sustainability and human nutrition, relegating these effects to other policy domains. To avoid possible conflict between different policies, expanded seed system monitoring systems are needed that include metrics on agricultural biodiversity, sustainability and human nutrition.

Notes

[3] The conservation function of seed systems is treated separately, in Chapter 5.

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Conserving agricultural biodiversity for use in sustainable food systems

CHAPTER 5

KEY MESSAGES:

- → **Often the many potential benefits of agricultural biodiversity to sustainable food systems are not realized because of poor conservation, lack of information and inadequate or restrictive policies.**
- → **Successful conservation takes an integrated approach that safeguards the genetic diversity in places where it has evolved, backs it up in *ex situ* facilities for posterity, and makes it readily accessible and available for use.**
- → **Only 12 crops and five animal species provide 75% of the world's food. Yet there are 1000s of neglected plant species and varieties with potential utility for humans, representing one of the most poorly utilized and underappreciated food resources we have. They must be conserved and used.**

What diversity to conserve for sustainable food systems

For the purposes of the Agrobiodiversity Index, we focus on diversity of animals and crops, as representative of the foundations of agriculture, but we can expand to cover fish, trees, and even landscapes, in future. For a sustainable food system at the national level, countries aim to conserve biodiversity which is important to people's food and nutrition security and farming systems, highly threatened, globally valuable and unique, or a combination of these.

Some countries are centres of diversity and origin of crops and animals and harbour a greater diversity of these species than others. For example, there are over 1483 varieties of Andean tuber species found in the Andean region of Peru. Often when crops are endemic, they also have large populations of related species in the wild, 'crop wild relatives' (CWR), which can be a valuable source of traits for breeding improved varieties. South Africa, for instance, is a significant centre of biodiversity, with more than 12,000 endemic plant species and many CWR, including sorghum, sweet potato and cowpea. In other cases, certain species have become foundational in local farming systems over generations – e.g. banana-based production systems in Eastern Africa. Similarly, certain flavours are important in local cuisine – e.g. *Garcinia cowa* (a relative of mangosteen) is important in some parts of Thailand, where the leaves are a traditional flavouring ingredient (1).

The greatest threat to agricultural biodiversity is the ongoing simplification of diets and farming systems (2). From the pool of 40 animal species and 5,538 plant species documented as human food (3), only 12 crops and five animal species provide 75% of the world's food (4).

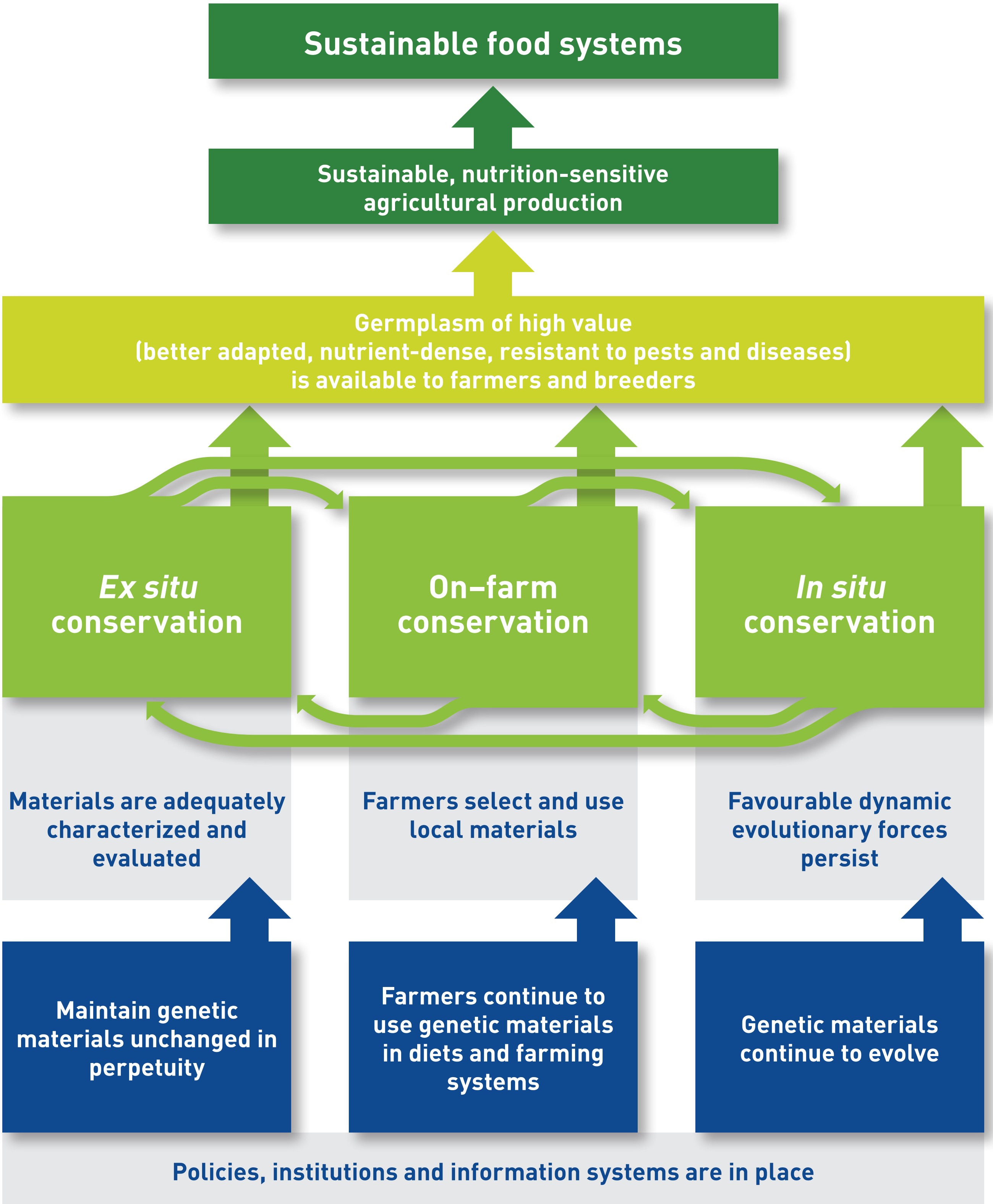
And yet, the genetic diversity conserved on and around farms continues to be remarkable. A study in Benin found that households grew and collected 65 species over a year – including crops and fruit trees, wild trees and bushes (5). Similarly, single home gardens around the world often harbour 20 to 50 different plants and several small livestock species (6). Many of these are highly nutritious, adapted to marginal farming conditions or both. Most have never been formally improved and so, despite their value, are neglected by national conservation efforts ('neglected and underutilized species' or NUS).

How to conserve

Government strategies to conserve agricultural biodiversity are based on consideration of the purposes for conserving it, the biology of the species and an assessment of benefits and challenges. Cultivated plants can be conserved as an embedded part of local agricultural practices and cuisines (on-farm conservation), or they can be removed from their original location and safeguarded *ex situ*, for example in a genebank or a botanical garden. It is difficult to conserve animals anywhere apart from on farm, though strides are being made to conserve biological samples in tissue banks (4). CWR can be conserved where they occur in their natural habitat (*in situ*), by taking measures to preserve that area, or they can be conserved *ex situ*. These three options – on-farm, *in situ* and *ex situ* – are all necessary, but none is sufficient on its own, as each serves different purposes and each has merits and limitations (Fig. 5.1).

FIGURE 5.1 THE THREE REALMS NEEDED FOR EFFECTIVE CONSERVATION OF GENETIC RESOURCES

The grey boxes are starting conditions that must be in place for conservation to be effective. Dark blue are the aims of conservation, green are the three realms and dark green are the higher goals.
The arrows between the realms show the features of an integrated conservation system – the interconnectedness between diversity held on farm, *in situ* and *ex situ*: diversity held *ex situ* is available to breeders and farmers and can be used to restore diversity on farm and *in situ*; gene flow from wild relatives to cultivated species on farm can increase resistance; and long-term conservation *ex situ* acts as a back up for on-farm and *in situ* biodiversity.



On-farm conservation

Where the purpose is that communities should continue to benefit from the availability of crop and animal biodiversity, one strategic option is on-farm conservation. On-farm conservation is the result of networks of different farmers doing different things over large areas – i.e. each engaged in their own livelihood and risk management strategies, and adapting crops to their own niche environments – with the inadvertent end result across a region or country that a wide range of diversity is conserved (7).

The advantages of on-farm conservation are that the diversity continues to evolve in response to natural and human selection, and that it covers thousands of species, breeds and varieties. Challenges are that the diversity is susceptible to threats such as disease, conflict and changing climate, land use and farmer choices. To strengthen conservation through use, community seedbanks, nurseries or animal management can be used. For example, in a subsistence agriculture community in the Limpopo area of South Africa, establishment of a community seedbank halted the loss of traditional crops and varieties central to farming systems and survival (8).

In situ conservation

Where the purpose is the continued evolution of novel traits for breeding, conservation in the wild and on farm (i.e. *in situ*) is a strategic choice. The wild relatives of crops and animals serve as a large repository of genetic diversity of value for crop and animal improvement, which for crops is valued at more than US$ 120 billion per year. They are potential sources of traits beneficial to crops and domesticated animals, such as pest or disease resistance, yield improvement or stability. For example, in the 1970s the US maize crop was severely threatened by corn blight, which destroyed almost US$ 1,000 million worth of maize and reduced yields by as much as 50% in 1978 (9). The problem was resolved through the use of blight-resistant genes from wild varieties of Mexican maize (10).

Where the purpose is to keep the maximum diversity on farm or in the wild to maintain a large pool of evolving genetic resources, but the use for local communities is low, extrinsic incentives can be used, such as providing rewards to communities for conserving target plant or animal populations (11).

Ex situ conservation

Ex situ conservation conserves agricultural biodiversity unchanged, and widens access to that diversity far beyond the limited site where it grew or was cultivated. Typically, the choice of the type of conservation method depends on the biology of the species conserved and on the facilities available for storage. These include seedbanks (for seeds), field genebanks (for live plants), *in vitro* genebanks (for plant tissues and cells), pollen banks and DNA banks, and cryobanks for ultra-long preservation (12).

Challenges to *ex situ* collections include securing long-term funding, capacity to keep the collections alive and healthy, and political instability, including wars. Having

Bolivian farmer in a quinoa field.
Credit: Bioversity International/E.Gotor

Wild onion, Italy.
Credit: Bioversity International/A.Lane

Banana accessions conserved *in vitro* at the world's largest banana genebank - the Bioversity International *Musa* Transit Centre in Leuven, Belgium.
Credit: Bioversity International/N.Capozio

backup collections in different countries and continents (such as the Svalbard Global Seed Vault) is a good strategy to ensure that collections are safely duplicated and maintained at high international standards. So far genebanks have mainly focused on staple crops; non-staples and CWR are poorly represented (about 2%) (13). This is partly because in many cases the biology of CWR is unknown, so scientists do not know if they have seed that can be stored for long periods or if they need to use alternative methods, such as cryopreservation.

Enabling environment

One key policy element to support national conservation of agricultural biodiversity is coordination between different ministries. For example, in Mexico, interdepartmental cross-cutting commissions have been established for biodiversity and sustainable development (14). Diverse policies – e.g. trade, agriculture, biodiversity conservation and forestry, education, food security, seed laws and plant protection – act as forces that affect agricultural biodiversity conservation. Policies can deliberately support on-farm conservation as part of the national conservation system, for instance by recognizing farmers who conserve and promote biodiversity ('custodian farmers'), as the government of Bolivia did in 2014.

An effective, functioning system of integrated conservation relies on the availability of and access to information on the extent of genetic diversity present *ex situ*, on farm and *in situ*. Yet, such an information system is lacking at national levels. At the global level, there are a number of important databases documenting animal genetic resources and plant genetic resources held by the major genebanks. There are local efforts to document biodiversity community by community through Community Biodiversity Registers and catalogues. They have potential to be digitized and linked into powerful country databases of on-farm diversity.

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Towards an Agrobiodiversity Index for sustainable food systems

CHAPTER 6

KEY MESSAGES:

- **Agricultural biodiversity is measured in many ways: linked to healthy diets, sustainable land use, agriculture, climate change adaptation, resilience and biodiversity conservation.**
- **Bioversity International proposes the development of an Agrobiodiversity Index that brings agricultural biodiversity data together in innovative combinations across those functions in the food system to give novel insights, help countries identify policy levers, and be usable in real time to guide companies and investments.**
- **We welcome input from readers, experts and potential users for the development and utility of the Agrobiodiversity Index for sustainable food systems.**

Why an Agrobiodiversity Index is important for sustainable food systems

Agricultural biodiversity sits at the nexus of different dimensions – diet quality, production systems, seed systems and conservation. The evidence summarized in the previous pages indicates that each dimension has key areas contributing to sustainable food systems (Table 6.1).

There are clear connections between them. On-farm conservation is carried out through the use of genetic diversity by farmers in the daily management of their farms. Innovation in seed systems is linked to healthy diets through selecting or breeding nutrient-dense crops.

Many indicators and methods have been developed and applied to measure these aspects of agricultural biodiversity. The metrics in Table 6.1 highlight the pathways that connect agricultural biodiversity to diet quality, sustainable agriculture, ecosystem services, the health of seed systems and biodiversity conservation.

> *Food systems must be fundamentally reoriented around principles of diversity, multi-functionality and resilience.*
>
> IPES-Food, 2015

TABLE 6.1 KEY AREAS OF AGRICULTURAL BIODIVERSITY THAT CONTRIBUTE TO SUSTAINABLE FOOD SYSTEMS

DIET QUALITY	PRODUCTION SYSTEMS	SEED SYSTEMS	CONSERVATION
Dietary diversity	Diversity within species	Facilitating access	On-farm diversity
Food biodiversity on farms and in the wild	Diversity among species	Production and distribution	*Ex situ* diversity
Food biodiversity in markets	Diversity at farm and field level	Innovation	*In situ* diversity
Enabling environment	Diversity at landscape level	Regulation	Enabling environment
	Enabling environment	*Conservation**	

*Conservation is a key area of seed systems, but also an important dimension in itself.

To manage agrobiodiversity, we need to measure it.

The variety in measurements related to agricultural biodiversity is both its strength and its weakness. Its strength: because data on agricultural biodiversity's contribution to each of these goals is collected and has raised awareness across relevant sectors, Sustainable Development Goals and the Convention on Biological Diversity Aichi Targets. Its weakness: because the data, information and metrics are scattered across disciplines (e.g. conservation, ecology, agriculture, markets, nutrition) and scales (from crop varieties to species to ecosystems). There is a gap in terms of tools and approaches for quantitatively synthesizing existing and emerging data into actionable trends, dynamics and summaries. This limits the effective management of agricultural biodiversity to contribute to sustainable food systems.

Bioversity International proposes to develop an Agrobiodiversity Index, which brings agricultural biodiversity data together in innovative combinations across dimensions of the food system. The Index will provide novel insights to help countries identify policy levers. It will be usable in real time to guide companies and investments.

Learning from existing agricultural biodiversity data, metrics and monitoring: five summary points

1. Aspects of agricultural biodiversity are **measured throughout the food system** (Table 6.2) but are not connected. Connecting them helps identify constraints, trade-offs and synergies to guide action. For example, if agricultural biodiversity is increasing in production, but not in diets, there is potential to strengthen markets or nutrition education to increase consumption of food biodiversity.
2. Applying a **consistent set of simple agricultural biodiversity indicators** (e.g. number of food groups, commonly used measures of biodiversity) across dimensions (diets, production, seeds, conservation) enables such trends to be identified and compared (2–4).
3. **Existing crop and livestock data can be combined with remote sensing and spatial modelling** to create global and national agricultural biodiversity maps (e.g. Herrero et al., in preparation), which trigger novel insights into the spatial distribution of agricultural biodiversity and can be overlapped with other spatially explicit data, for example on the Sustainable Development Goals.

Fruit and nut trees in Tajikistan. Apple, apricot, almond, cherry, grape, pistachio and walnut are some of the many temperate fruit trees that originated in Central Asia. Yielding fruit and nuts even on poor land, these perennial trees can transform the surrounding landscape to encourage the growth of other crops. They are also culturally, nutritionally and economically vital to the region. Credit: Bioversity International/B.Vinceti

4. **Drivers and the enabling environment** for agricultural biodiversity in food systems are often more feasible to measure than the actual state of agricultural biodiversity and also provide a critical way to identify entry points for action. For example, genetic diversity is notoriously difficult to measure – many potential measures have been suggested each with pros and cons (5) – whereas drivers such as 'number of crop improvement networks' (6) are relatively easy to measure and likely to correlate well.
5. **Citizen science and crowdsourcing** are increasingly used in biodiversity monitoring (7). Linking high-level monitoring efforts with local crowdsourced agricultural biodiversity information in the Index is a highly innovative development. It will allow the correlation between indicators and actual status of biodiversity to be ground-truthed, increase sensitivity to capture change, and make the Index applicable at different spatial scales.

Learning from other composite indexes: five summary points

1. Various types of indexes can be distinguished based on the audience targeted and the data used. One type uses national datasets, aggregates well-established indicators, and mainly targets national governments. Examples are the Global Biodiversity Outlook, Global Food Security Index, Global Hunger Index and the Environmental Performance Index. A second type also targets national governments and related stakeholders but collects input data via index-specific questionnaires with samples of experts or stakeholders – like the Corruption Perceptions Index, and the Ease-of-Doing-Business Index. This type is particularly useful for issues that are difficult to quantify. The Access to Medicine, Access to Seeds, Access to Nutrition type indexes focus on companies and use company-specific information. Some of the indexes capture outcomes, others focus on drivers, and others combine both outcomes and drivers.
2. Composite indexes are helpful to articulate **multiple dimensions** of a certain issue. Analysis of trends of sub-indexes allows policymakers to identify entry points for action.
3. **Many datasets exist**, often collected at great expense, and increasingly experienced as information overload. There is a growing demand for indexes that summarize these data to make them usable in decision-making.
4. Most robust indexes are developed, improved and adapted over time through an **iterative process**, validating proposed measures scientifically and from a user perspective and adjusting accordingly.
5. An under-explored opportunity exists to mobilize recent **digital innovations**, such as crowdsourcing for input of data to construct composite indexes.

Perspective for an Agrobiodiversity Index

We start from the demand side. Four user groups have expressed strong interest in using an Agrobiodiversity Index to measure and manage actions towards developing sustainable food systems:

- National and local governments – to guide progressive food, agriculture and conservation actions and monitor progress towards global goals
- Companies – to robustly and transparently rate food and agriculture companies listed on stock markets, and identify ways to implement sustainable business practices that increase long-term shareholder value, both by reducing risks in the supply chain and by enhancing attractiveness to consumers
- Public and private investors – at a project or investment level, to guide and track investments in sustainable bond markets, which contribute capital to sustainable environmental and climate-focused development projects
- Farmers, consumer groups and local organizations – to inform their decisions about sustainable practices and purchases and to influence programmes and policies.

The Agrobiodiversity Index must be fit for purpose and easy to use. It can be tailored in different ways to provide the decision-supporting knowledge that these different user groups need. It should also be easy to contribute to and use data from the Index. Three incentives include:

- Making current data collection easier through investment in lean data approaches, i.e. tailored, focused questions delivered directly to key users through low-cost technologies
- Sharing data directly in compelling visualizations, scorecards and dashboards in near real time, to aid and inform decision-making
- Shaping new institutional, business and innovative financing arrangements involving agricultural biodiversity to connect data for use in risk management.

Figure 6.1 illustrates how we envision the Agrobiodiversity Index tool functioning. The proposed Agrobiodiversity Index might not be comprehensive initially but aims primarily to be actionable and to grow over time.

A first step will be to combine existing datasets, integrating crop and livestock data for agricultural biodiversity measures. These high-level monitoring efforts can then be enriched with local crowdsourced agricultural biodiversity data and, where feasible, remote-sensing data. Another key information source that is easy to locate is to screen policy, progress and annual reports for factors that create an enabling environment for agricultural biodiversity.

A next step will be to test the feasibility of an Agrobiodiversity Index for multiple uses (national governments, investors, companies) by further engaging with stakeholders and piloting an initial design. We thereby welcome input from readers, experts and potential users for the development and utility of the Agrobiodiversity Index for sustainable food systems.

TABLE 6.2 ILLUSTRATION OF INDICATORS, BOTH EXISTING AND PROPOSED, THAT MEASURE AGRICULTURAL BIODIVERSITY AND ITS CONTRIBUTIONS TO DIMENSIONS OF A SUSTAINABLE FOOD SYSTEM

Agricultural biodiversity contributing to...

HEALTHY, DIVERSE DIETS

DIET DIVERSITY

- Minimum diet diversity for children and women
- % consumption of targeted food groups
- Dietary Species Richness (number of different plant and animal species per human per day)
- Grams and dietary energy per capita of different food groups/items
- % dietary energy from non-staples

MARKET/ VALUE CHAIN DIVERSITY

- Prices of principal foods representative of diverse food groups
- Ultra-processed food retail (vol/capita)
- Fresh food retail (kg/cap)
- Diversity of retail outlets for elements of a healthy diet
- Average price of a healthy diet

ENABLING ENVIRONMENT

- Consideration of ABD in a country's National Dietary Guidelines
- Food subsidies and public procurement programs in place that promote ABD for diets/nutrition
- Consideration of ABD mainstreaming for diets/ nutrition in NBSAPs
- Multisectoral nutrition strategies

MULTIPLE BENEFITS IN SUSTAINABLE FARMING SYSTEMS

DIVERSITY WITHIN SPECIES

- Varietal diversity of major crops on farm
- Varietal diversity of major crops in markets

DIVERSITY AMONG SPECIES

- Evenness/diversity of production area and yield across crops by nation

DIVERSITY AT FARM AND FIELD LEVEL

- Evenness/diversity of production area and yield across crops by nation
- % land that is degraded over total land area
- % agricultural area under sustainable agricultural practices

DIVERSITY AT LANDSCAPE LEVEL

- Landscape and land-use heterogeneity
- Coverage (e.g. extent) of habitat related to particular ecosystem services (e.g. pollinator habitat)

ENABLING ENVIRONMENT

- Policies that explicitly aim to conserve and/or promote ABD
- National policies and incentives around multiple ecosystem services in agricultural landscapes

CROP DIVERSITY FOR SUSTAINABLE FOOD SYSTEMS

SEED ACCESSIBILITY

- Information availability
- Amount and diversity of seed sources
- Proximity of seed sources
- Seed price

SEED PRODUCTION AND DISTRIBUTION

- Amount of seed produced and distributed
- Range of crops and varieties multiplied and distributed
- Number and diversity of seed multipliers and seed suppliers

CROP INNOVATION

- Range of species covered by innovation efforts
- (Local) genetic diversity used in innovation efforts
- Degree of recognition of farmers as innovators in intellectual property right systems

REGULATIONS

- Extent to which variety registration procedures allow for the release of varieties responding to different environmental and socio-economic conditions
- Extent to which seed quality control and certification schemes respond to different types of seed producers and farmers

CONSERVATION FOR USE IN SUSTAINABLE FOOD SYSTEMS

ON-FARM CONSERVATION

- Percentage of cultivated land under farmers' varieties/landraces in areas of high diversity and/or risk
- Number of local breeds by species and region

***IN SITU* CONSERVATION**

- Trends in population size of target Crop Wild Relative population
- Crop Wild Relative Index based on IUCN Red Listing

***EX SITU* CONSERVATION**

- number of species conserved *ex situ* under medium or long-term conditions
- % crop species native or exhibiting a wide diversity conserved in *ex situ* collection
- Enrichment Index

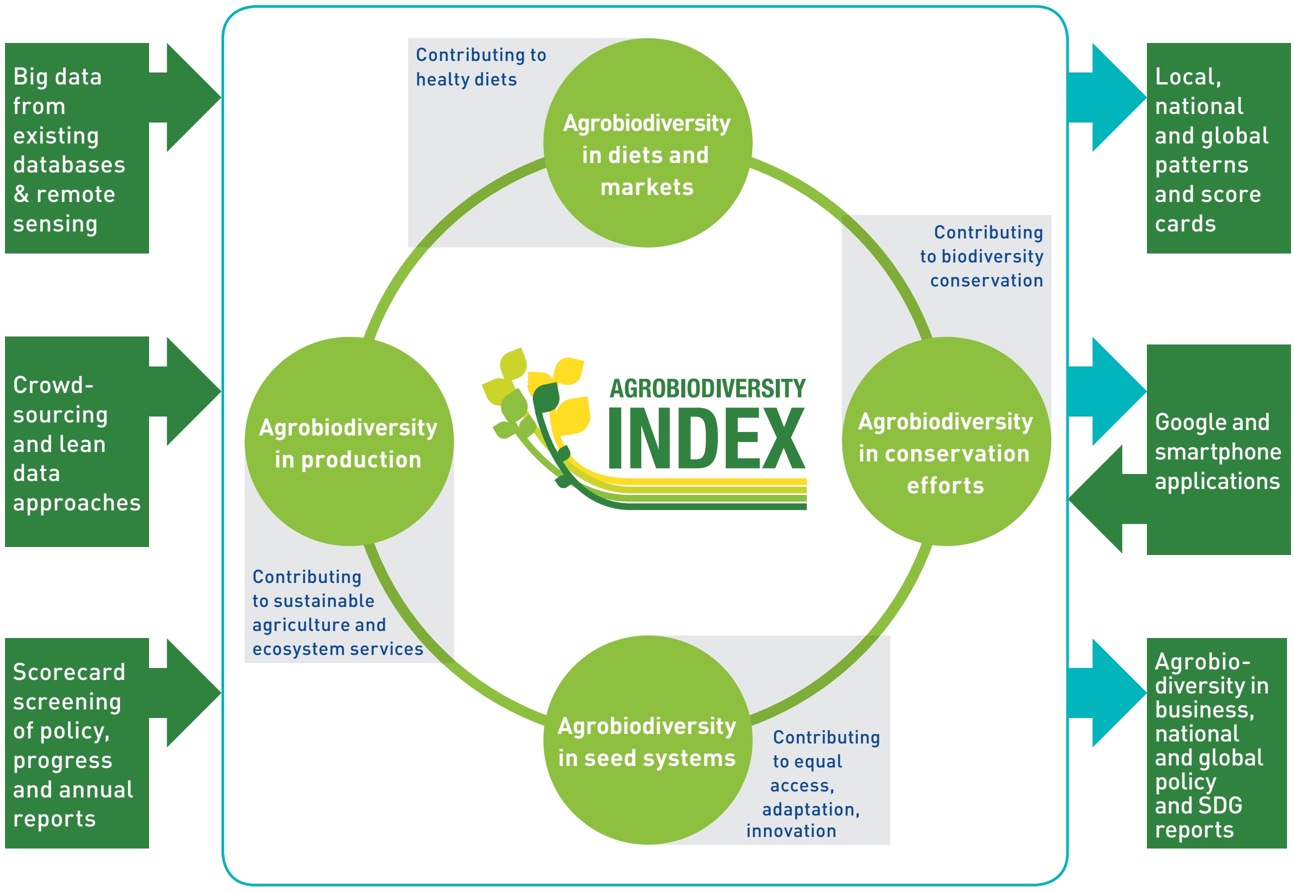
ENABLING ENVIRONMENT

- NBSAP includes ABD
- Farmers and their knowledge recognized and their role explicitly facilitated
- Regional, local ordinances to support ABD conservation/use.
- Participatory, broad-based development of strategies and implementation plans specifically targeting participation of women farmers

ABD = agricultural biodiversity, NBSAP = national biodiversity strategy and action plan

FIGURE 6.1 CONCEPTUALIZATION OF THE AGROBIODIVERSITY INDEX

The Agrobiodiversity Index will draw on input from existing databases, combined with crowdsourcing data and a screening of public and private policies and reports on issues connected with agricultural biodiversity's contribution to global goals. Users can consult scorecards and access – and input – information through mobile applications. The results from the Agrobiodiversity Index can be used to report on commitments to global goals, and to stakeholders, such as the public.



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RESEARCH PROGRAM ON Agriculture for Nutrition and Health

This research contributes to the CGIAR Research Program on Agriculture for Nutrition and Health.

ISBN: 978-92-9255-059-2