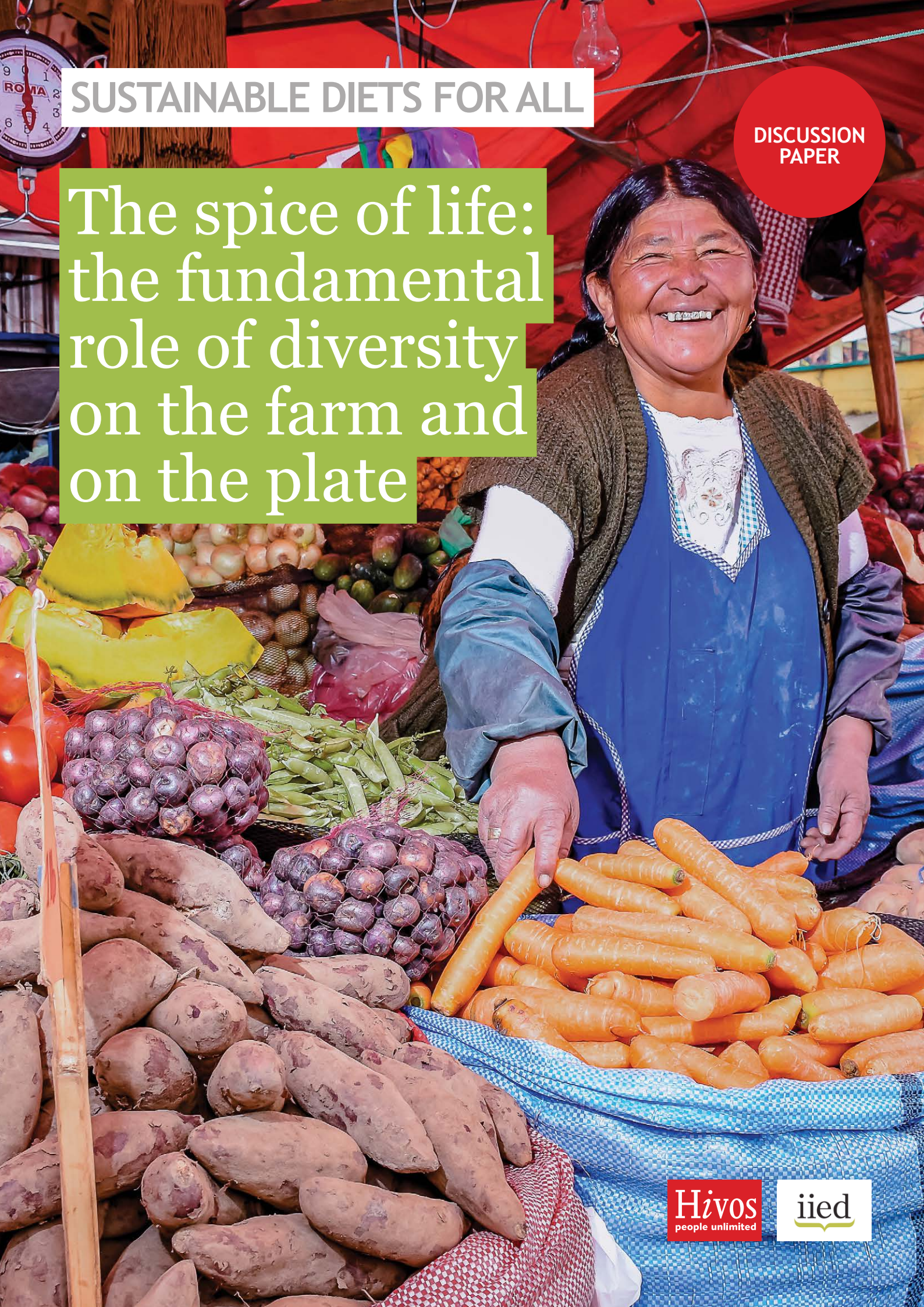
SUSTAINABLE DIETS FOR ALL

DISCUSSION PAPER

The spice of life: the fundamental role of diversity on the farm and on the plate



Hivos people unlimited

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CONTENTS

ACRONYMS, ABBREVIATIONS AND TERMS

Agroecosystems — those ecosystems that are used for agriculture

CAFO — concentrated animal feeding operations

Commercialisation — the proportion of agricultural sales in the total value of a household's agricultural production

Cultivar — same as variety

Dietary diversity — the number of foods or food groups consumed over a specified period of time

GI — geographical indication

Heirloom variety — an old plant variety maintained by farmers and gardeners

Hybrid — crop varieties that have been produced from the combination of genetic material from different varieties

Informal markets — those markets which are not formally taxed or regulated

IPRs — intellectual property rights

Landrace — a crop variety that has been generated, adapted and maintained by farmers

Monoculture — growing the same crop on the same land repeatedly

NCDs — noncommunicable diseases

PPB — Participatory plant breeding

SD4All — Sustainable Diets for All Programme

Species — a group of organisms capable of interbreeding and producing fertile offspring

Variety — a group of cultivated plants clearly distinguishable by shape, colour and flavour

SUMMARY

Smallholder farmer in his maize field in Zambia (Wesley Wakunuma)

The world is witnessing major shifts in dietary patterns and — in parallel — a significant threat to agricultural biodiversity. The implications for human health and the resilience of our food systems are far reaching. As this paper shows, these two phenomena are interconnected. It calls for action to reverse these trends, in order to put diversity back in our farming systems and on our plates and to preserve it where it still exists. Drawing on literature review, action research, innovation and multi-stakeholder platforms in Indonesia, Uganda, Zambia and Bolivia as part of the Sustainable Diets for All Programme coordinated by Hivos, IIED and partners, the paper explores how this situation has come about and suggests what can be done. Its aim is to inform policymakers, agriculturalists and civil society working on these issues.

Diversity is declining — and with it, our health

Today 30 crops supply 95 per cent of the calories that people obtain from food, and only 4 crops — maize, rice, wheat and potatoes — supply over 60 per cent. To take just one example: four varieties of apple dominate global markets today, compared with over 7000 that existed at the beginning of the 20th century. The same loss of diversity is occurring among animal breeds too. Such heavy reliance on a narrow range of crops, crop varieties and animal breeds is risky — for agricultural production, for livelihoods, and for nutrition. A key risk is that it undermines the ability of agriculture to adapt to climate change, and to cope with pests and diseases.

The threat to agrobiodiversity is occurring within a general rate of species extinction estimated to be 100 to 1000 times the natural rate. Approximately 21 per cent of plant species and 17 per cent of all animal breeds are at risk of extinction — a trend that also threatens agriculture. Biodiversity loss is one of the areas where humanity is operating furthest outside the planet's environmental limits.

Coinciding with the threat to agricultural biodiversity, and partly linked to it, is the trend towards the homogenisation of diets and the greater intake of calories, animal protein and fat, and ultra-processed foods that are high in sugar, salt and fat. This trend is most pronounced among the increasingly urbanised segment of the world's population with rising incomes. Diet-related health problems now exceed those stemming from undernutrition in virtually every part of the world, and noncommunicable diseases (NCDs, e.g. diabetes, metabolic disorders, hypertension, coronary heart disease and some cancers) are now the leading cause of death worldwide. Without effective measures to address them, the social and economic costs of NCDs will continue to rise, exceeding the capacity of countries to cope with them.

The solution lies in a food systems approach

This paper explores the roots of this situation and asks how to reorient food systems towards greater diversity, health, sustainability and inclusiveness. It argues that diverse agricultural production and diverse diets can be mutually reinforcing. Agricultural biodiversity is vital for the functioning of agroecosystems, controlling pests and diseases, soil health, pollination, and mitigating climatic and economic risk and is an integral component of sustainable agriculture. Diversity is also a key element of healthy, high-quality diets and is the most important factor in providing the spectrum of micronutrients essential for human health. Given that consumer demand and purchasing power shape the incentives that farmers have to maintain a diverse array of crops, promoting diverse diets helps to conserve agricultural biodiversity and support rural livelihoods. At the same time, diverse agricultural production can make a wide variety of foods available to consumers.

Goats on a farm in Fort Portal, Uganda (Nimrod Bagonza)

In bringing together food production and consumption, diets and health, this study takes a food systems perspective. The global food system is multifaceted, and it is essential to reorient the current focus on production towards a more holistic approach which also encompasses access, distribution and governance, consumption and waste, markets and livelihoods. Food systems thinking can highlight the connections between all of these different elements, breaking down silos in the process.

Food systems and the policies that affect them need to become more inclusive and responsive to the needs of farmers and consumers alike. Currently, many key actors — such as farmers, consumers and informal economy workers — do not participate in the governance of local food systems. In order to make them more inclusive and to cope with the complexity of food system issues, multi-stakeholder approaches are needed that can ensure the voices of all relevant groups are heard — particularly the smallholder farmers and women who play a critical role in safeguarding agrobiodiversity and the diversity on our plates, but who are often marginalised from decision-making processes. Women are both farmers themselves and also often the household members with the most central role in making food purchases and preparing meals — key arenas where food choices play out.

Five actions for fostering food diversity

The paper proposes five actions for fostering diversity on the farm and on the plate:

1) Reorient food, nutrition and agricultural policies to encourage diversity, nutrition, sustainability and affordability, rather than only prioritising a small number of staple crops; promoting food systems analysis and action can help.

2) Use markets to support diversity in production and consumption by allowing informal markets to thrive, using procurement, and investing in local innovative agri-food businesses that promote diversity.

3) Promote and maintain local crop varieties, animal breeds and under-utilised crops through developing markets for them, adjusting extension services and fostering synergies between scientific and local knowledge.

4) Nurture the biocultural heritage and traditional knowledge that underpin much of the world's remaining agricultural biodiversity, including by protecting the rights of women.

5) Increase awareness and catalyse change through innovative multi-stakeholder approaches like food labs, that explicitly bring in the voices and perceptions of farmers and consumers, including women and youth.

While implementing these suggested changes will not be easy, they are necessary to break the current cycle of decline in agrobiodiversity and diets.

KEY MESSAGES

Sustainably produced vegetables (Simon Lim)

- Agricultural biodiversity is vital to the functioning of agroecosystems, to ensure food and nutrition security and to cope with the challenges of climate change.
- The world's rich agricultural biodiversity is currently at risk as agricultural landscapes become increasingly simplified and the number of crops, crop varieties and animal breeds on farms declines.
- Heavy reliance on a narrow range of crops, crop varieties and animal breeds brings long-term risks for agricultural production, biodiversity, livelihoods and nutrition while undermining the ability of agriculture to adapt to climate change.
- Diversifying and improving diets is essential to human health and to limiting the spread of noncommunicable diseases.
- Diversity on the farm can and often does lead to diversity on the plate, but this is not always the case and depends on a number of critical factors such as gender and control over resources, markets, wealth, cultural values and preferences, as well as the existing level of diversity on the farm.
- Empowering women can contribute to diverse food production and varied, high-quality diets.
- Food, nutrition and agricultural policies need to be reoriented to encourage diversity, nutrition, sustainability and affordability, rather than only prioritising a small number of staple crops; promoting food systems analysis and action can help.
- Markets can support diversity in production and consumption by allowing informal markets to thrive, using procurement, and investing in innovative agri-food small and medium-sized enterprises that promote diversity.
- Local crop varieties, animal breeds and under-utilised crops should be promoted and maintained by developing markets for them, adjusting extension services and fostering synergies between scientific and local knowledge.
- Biocultural heritage and traditional knowledge underpin much of the world's remaining agricultural biodiversity and should be nurtured, including by protecting the rights of women.
- Innovative multi-stakeholder approaches like food labs can increase awareness and catalyse change through explicitly bringing in the voices and perceptions of farmers and consumers, including women and youth.

INTRODUCTION

The world's rich agricultural biodiversity is at risk, and with it our health and the resilience of our food systems. Agricultural landscapes are becoming increasingly simplified as the number of crops and crop varieties grown on farms declines. Responding to a variety of pressures, farmers have replaced many time-tested local varieties with a small number of modern ones — a pattern which holds true for both food crops and animal breeds. Coinciding with the threat to agricultural biodiversity has been a trend towards the homogenisation of diets. Today 30 crops supply 95 per cent of the calories that people obtain from food, and only four crops — maize, rice, wheat and potatoes — supply over 60 per cent.[1] This is noteworthy given that over the millennia, humans have domesticated or collected approximately 7,000 species of plants for food.[2] Such heavy reliance on an unprecedented narrow range of crops, crop varieties and animal breeds brings long-term and increasing risks for agricultural production, for biodiversity, for livelihoods, and for nutrition. It also undermines the ability of agriculture to adapt to climate change.[3]

On the surface at least, modern foods systems appear to be astonishingly diverse. Globalisation has ensured that a dazzling variety of foods is available. Each year, thousands of new food products take their place on the shelves. A person walking into a supermarket almost anywhere in the world is easily overwhelmed by the profusion of choices. Meanwhile, the sheer abundance of food produced by modern food systems is impressive. Global crop production has grown threefold during the past 50 years, driven mostly by higher yields per unit of land and crop intensification.[4]

Yet the abundance and variety of modern food systems are deceptive. Hunger and malnutrition persist in many countries in spite of increased food production. In the food industry, a few ingredients like refined flour, sugar, soy, palm oil and high fructose corn syrup appear over and over again in a plethora of different products. What seems to be variety is in many cases just endless re-engineering, re-combinations and repackaging of the same basic, highly processed ingredients.

Meanwhile, in spite of the apparent diversity in agricultural and dietary terms, modern food systems actually tend towards uniformity in production and marketing. Much of the food produced today — particularly in rich countries, but increasingly in the developing world as well — is grown in monocultures involving a small number of crop varieties. Fields of a single crop facilitate mechanised planting and harvesting, while meeting imperatives to maximise profits in competitive markets. The same trend holds for industrial livestock. At the same time, the need for standardisation in shipping, packaging and display on the part of large supermarket chains has meant that uniformity in the form and appearance of produce is prioritised. This has resulted in commercial pressures on producers to focus on growing a small number of crop varieties and animal breeds that meet these criteria and the displacement of those that do not.[5]

As a result, the world's rich agricultural biodiversity is at risk. The threat to agrobiodiversity is occurring within a general rate of species extinction estimated to be 100 to 1,000 times the natural rate.[6] Approximately 21 per cent of plant species[7] and 17 per cent of all animal breeds[8] are at risk of extinction — a trend that also threatens agriculture, in that biodiversity underpins agricultural production. In fact, biodiversity loss is one of the areas where humanity is operating furthest outside planetary boundaries — the earth's environmental limits.[9]

The threat to agrobiodiversity is in turn related to changes in food consumption patterns. The world is in the midst of major shifts in dietary patterns towards higher consumption of refined carbohydrates, edible oils, added sweeteners and animal products, often accompanied by reduced consumption of legumes, fruits and vegetables.[10] Often termed the 'global dietary transition' or 'global nutrition transition', this is having serious health and environmental consequences, including high carbon and water footprints.[11]

Farmer in his matoke field in Fort Portal, Uganda (Nimrod Bagonza)

Although the nutrition transition is occurring more rapidly in urban than in rural areas,[12] and there are important differences between different socioeconomic groups and regions,[13] diets are becoming more and more similar in many parts of the world.[14] They are increasingly derived from a small number of crops such as wheat, rice, maize, sugar, palm oil, potatoes and soybeans. There has been a concurrent decline in the production and consumption of other crops such as sweet potatoes, yams, cassava, millets, rye and sorghum,[15] some of which (e.g. millets) are more nutritious than the crops that have replaced them.[16,17] The increasing homogeneity of global food supplies corresponds with a trend towards greater intake of calories, animal protein and fat in some people's diets, with higher proportions of ultra-processed foods that are rich in sugar, salt and fat. Consumption of excess calories is a key driver of obesity,[18] as is the higher consumption of energy-dense, nutrient-poor foods combined with lower levels of physical activity. Together these have led to epidemic levels of overweight and obesity, as well as other diet-related noncommunicable diseases (NCDs) such as diabetes, metabolic disorders, hypertension, coronary heart disease and some cancers.[19]

While more than enough food is produced globally to provide sufficient calories for every person on the planet,[20] more than 800 million people — one in nine — are hungry;[21] though the actual figures are likely to be much higher than this.[22] Meanwhile, some two billion people suffer from micronutrient deficiencies and another two billion are overweight or obese. Out of 667 million children under the age of five, about a quarter are stunted (too short for their age), 50 million are wasted (underweight for their height), and 41 million are overweight.[23] The estimated costs of malnutrition are $3.5 trillion globally, or 11 per cent of GDP.[24] By 2030 approximately 16–18 per cent of total healthcare expenditure will be on complications related to overweight and obesity if current trends continue.[25]

While the problems of hunger, malnutrition and obesity are complex, part of the solution is to foster greater diversity in food production and consumption. This paper explores why diversity is important on the farm and on the plate, and the relationship between them. The paper analyses the reasons why agricultural biodiversity and dietary diversity are at risk. It also makes recommendations for reintroducing diversity back into our fields and onto our plates, and for preserving diversity where it already exists.

In bringing together food production and consumption, diets and health, this paper utilises a food systems perspective.[26] It draws on literature review, action research, innovation and multi-stakeholder platforms conducted as part of the Sustainable Diets for All Programme.[27] Sustainable Diets for All is an advocacy programme that uses evidence, including evidence generated by citizens, to help low-income communities in Bolivia, Indonesia, Uganda and Zambia improve their access to sustainable, diverse and nutritious food. The five-year (2016–20) programme is coordinated by Hivos, the International Institute for the Environment and Development (IIED), and partners in the focal countries.

BIODIVERSITY AND THE FUTURE OF FARMING

The importance of agricultural biodiversity

The sheer abundance of food crops and crop varieties that humans have developed over the millennia is astonishing. For example, there are over 100,000 distinct varieties of rice (*Oryza sativa*).[28] In Peru, about 650 native potato varieties (1,350 according to the traditional classification system) are being conserved by indigenous communities in just one small region — the Potato Park near Cusco.[29] While it is difficult to calculate the economic value of agrobiodiversity, attempts have been made to value certain ecosystem services associated with it. For instance, pollination is estimated to underpin US$361 billion in crop production worldwide.[30]

Agricultural biodiversity — also known as agrobiodiversity (see Box 1) — is an integral part of agricultural systems in all parts of the world. Agricultural biodiversity is often viewed as a repository of genetic resources that can be drawn upon to improve modern animal breeds and crop varieties. While this is undoubtedly the case, it is far more than that. It encompasses a number of aspects, such as genetic resources, seeds, crops and edible plants, livestock, soil organisms, insects, bacteria and fungi.[31] Agricultural biodiversity is vital for the functioning of agroecosystems, soil health, pollination, controlling pests and diseases and hence should be treated as an integral component of sustainable agriculture.[32,33]

This chapter makes the case for the importance of biodiversity on the farm. It discusses the fact that this biodiversity is currently at risk, the reasons for this and its consequences. The focus is on cropping systems, with some comparative reference made to animal husbandry, where similar trends are in evidence.

Biodiversity in traditional vs. modern agricultural systems

Traditional agricultural systems are often characterised by high levels of diversity — both of crops and crop varieties. For thousands of years, indigenous peoples in Mexico and Central America have planted maize, beans and squash together rather than in separate plots. This combination of crops is known in Native American agriculture as the 'three sisters'. The agronomic system they comprise in Mexico is known as 'milpa' and is a form of polycropping that can deliver multiple benefits. Maize provides a trellis for the slower-growing bean vines, while the wide, shady leaves of the squash help to control the growth of weeds. Beans fix nitrogen, enriching the soil and contributing to the productivity of the system over the long term.[34] In fact, maintaining a diversity of crop species or varieties — either as rotations or through intercropping — can generate higher-than-average levels of production over the long term in some cases, although it does not guarantee higher short-term returns.[35] Moreover, crop diversification tends to be knowledge and labour-intensive, and its costs and benefits need to be assessed over longer rather than shorter time scales.[36]

Box 1. Agricultural biodiversity defined

Agricultural biodiversity or agrobiodiversity — the diversity of genetic resources (varieties, breeds, species; cultivated, reared or wild) used for food and agriculture, as well as for fodder, fibre, fuel and pharmaceuticals; the diversity of species that contribute to production as ecological communities (including pollinators, soil organisms, predators, etc.) and that help establish and maintain ecologically healthy farm landscapes and agroecosystems (agricultural, pastoral, forest and aquatic).

Source: FAO 1999

Modern crop varieties are characterised by their high productivity, a trait that enabled cereal production in Asia to more than double between 1970 and 1995.[37] Yet traditional crop varieties tend to be far more genetically diverse at the population level than the modern varieties that have replaced them.[38] They also tend to be more resilient and better adapted to local conditions (especially in marginal farming environments) than modern varieties.[39] In some cases they are more nutritious as well. Genetic

Banana plantation in Africa (by Pixabay https://pixabay.com/photo-2179178/)

material from traditional crop varieties and their wild relatives has contributed many key traits to breeding programmes for modern crops, including higher yields, pest resistance, drought tolerance, as well as adaptation to low temperatures and poor soils.[40]

Nutritional and ecological benefits of agricultural biodiversity

Planting diverse crops and crop varieties can enhance food security and nutrition.[41] The milpa system described above is a perfect example of this, in that the crops involved are nutritionally and agronomically complementary. Beans contain the amino acids lysine and tryptophan which maize lacks, and which the body requires to produce proteins and niacin. Beans lack the amino acids cysteine and methionine, which maize contains. Consumed together, maize and beans supply all of the required amino acids and thereby provide complete protein similar to meat. Maize supplies carbohydrates, while beans provide fibre, vitamins B2 and B6, iron, zinc, potassium, phosphorus, iodine and manganese. The milpa may contain multiple varieties of maize, beans and squash as well as chillies, avocados, melons, tomatoes, sweet potatoes, jicama and amaranth. Squashes provide vitamin A and other nutrients, as do the other vegetables. Avocados provide high-quality fats. In the words of maize researcher H. Garrison Wilkes of the University of Massachusetts at Boston, the milpa "is one of the most successful human inventions ever created".[42]

Integrated or mixed agricultural systems such as rice-duck and rice-fish farming can also yield ecological and nutritional benefits. In the former case, ducks are brought into the rice paddies 10-20 days after rice transplantation. The ducks feed on insects and weeds within the paddies, thus protecting the rice crops while averting the need for weeding and for pesticide applications. The duck droppings provide natural fertilisers for the rice crops. The system decreases the costs of inputs for rice production, while providing farmers with a good source of protein as well as additional income from selling the ducks and their eggs. Rice yields in this system can increase by up to 20 per cent, with up to 50 per cent higher net returns due to increased yields, lower production costs and income generated by the sale of duck meat and eggs.[43] There is also evidence that rice-duck farming can reduce methane emissions compared to conventional rice production.[44] However, the disadvantage of the rice-duck farming system is that it can be more labour intensive than conventional rice production, which can be a barrier to adoption in rural areas where labour is scarce.[45]

There are many ecological benefits to higher levels of diversity in agricultural systems, such as their greater potential for resilience to climatic and other stresses.[46] Agrobiodiversity contributes to key ecosystem functions such as nutrient and water cycling, as well as the breakdown of toxins (e.g., pesticides). Diverse agroecosystems also provide critical ecosystem services such as pest and disease control,[47] the subject of the next section.

Curtailing pests and diseases

There are many successful cases of pest and disease suppression in diverse agroecosystems.[48] Growing a diversity of crops and crop varieties can help control pests and diseases by curtailing their spread.[49] Large-scale experiments conducted in Yunnan province by Chinese and foreign agronomists have shown that intercropping two different varieties of rice increased yields by up to 89 per cent while reducing the incidence of fungal disease by 94 per cent compared to those grown in monocultures.[50] This was simply because the physical separation of different rice varieties made them less susceptible to rice blast. What is noteworthy about this technique is both its simplicity, and its similarity to traditional cultivation techniques which eschewed monocultures in favour of intercropping. Another key finding of the study was that as more farmers began planting the two different rice varieties together, the effects began to snowball, drastically curtailing the spread of the rice blast disease.[51] Reducing the problem of pests and diseases also means that fewer pesticides have to be applied to fields, thereby reducing inputs costs and increasingly profitability for farmers. The intercropping proved so effective at disease control that fungicidal sprays were no longer needed by the end of the two-year experiment. Conversely, planting fewer crop species is associated with higher pest pressure and pesticide use.[52] Utilising local crop varietal diversity is one of the few resources that small-scale farmers in developing countries have at their disposal to reduce crop losses from pests and diseases, together with the knowledge to effectively manage and use this diversity.[53]

Spatial heterogeneity in agroecosystems — such as with agroforestry borders and plots, vegetation banks, grass strips and hedgerows — can also have benefits for pest control. Agricultural systems that harbour higher plant biodiversity foster greater resilience by providing habitat for natural enemy populations, which in turn can protect crops from an array of pests.[54] For example, coffee agroforestry systems integrate shade trees within the cropping system. These systems have greater natural enemy populations as well as higher bird density and diversity than unshaded coffee monocultures, helping keep pests in check.[55] A similar dynamic has been observed with predatory ground-dwelling ants, which are more diverse and better able to prey upon the coffee berry borer — an important pest in coffee production — in shaded coffee agroforestry systems than in unshaded monocultures.[56]

Mitigating risk

Planting diverse crops and crop varieties also serves as an insurance policy against risk. If one crop fails, another may still produce. For example, farmers in the harsh environment of Northwest China use crop rotations of wheat, potatoes, alfalfa, millet and other crops to ensure a harvest in the face of climatic uncertainty.[57] Chinese farmers in this region also intercrop wheat and corn, which increases water use efficiency by taking advantage of the temporal differences in water demand between the two crops.[58] Making optimal use of scarce water resources is especially important in dryland environments.

Intercropping and crop rotations can both help to curtail risk while contributing to ecosystem stability.[59] A study in Malawi that compared monoculture maize with legume-diversified maize found that biodiversity improved agroecosystem function and fertiliser efficiency: rotation systems with semi-perennial legumes and only half the original applications of fertiliser produced similar yields to those of monocultures, while reducing yield variability and increasing nitrogen in the soil.[60] Farmers in Zambia traditionally have planted maize together with other crops such as sorghum, pumpkins, cow peas and Imisale (a local variety of sugar cane). In northern Zambia, cassava was often intercropped with millet. Not only does planting a diversity of crops help to cope with climatic risk — it also helps to mitigate the economic risk entailed by constantly fluctuating crop prices, as well as the food security risk if the main staple fails. However, these practices are increasingly being abandoned in favour of monocropping.[61]

Planting diverse varieties of the same crop can serve the same purpose.[62] For instance, Yucatec Mayan farmers plant a range of short-cycle and long-cycle maize varieties, whose different maturation times help to ensure a stable food supply throughout the year. This practice also spreads out the labour needed for planting, weeding, harvesting and threshing, thereby making farmers' workloads more manageable, minimising risk and ensuring household food security despite an uncertain and often adverse environment.[63]

Diverse maize varieties (Serena Mlano for Slow Food)

Risk mitigation is particularly important in the face of climate change. Climate change already poses a major challenge to agriculture and this trend is likely to accelerate in the coming decades.[64] It is expected to cause significant reductions in crop yields — up to 30 per cent for maize in southern Africa and up to 10 per cent for staples such as rice in South Asia by 2030.[65] In this context, future food security depends upon the ability of agriculture to adapt to climatic change. Crop and varietal diversity has a critical role to play as it can make agroecosystems more resilient, providing resilient germplasm and options for future adaptation.[66] Equally important for adaptation is maintaining the local knowledge and practices associated with this diversity.[67]

Agricultural biodiversity at risk

In spite of the many virtues of biodiversity on the farm, it is currently at risk. The genetic base of the world's principal food crops has narrowed considerably.[68] Since the 1960s, the replacement of traditional crop varieties with modern varieties has occurred at a rapid rate. By 1990, 70 per cent of the land in developing countries sown to rice and wheat was planted with high-yielding varieties, compared with 20 per cent for wheat and 30 per cent for rice in 1970.[69] By 1983, a single variety of wheat was being planted on 67 per cent of Bangladesh's wheat fields, and on 30 per cent of India's one year later.[70]

The fruit market epitomises the dominance of a small number of varieties. Only four commercial varieties of apples — Golden Delicious, Red Delicious, Gala and Granny Smith — currently make up 90 per cent of the world market.[71] In Italy alone, three apple varieties account for 80 per cent of production, although farming manuals at the beginning of the 19th century mention about 100 varieties.[72] Of the 2,500 types of pears that were grown in the past, today just two varieties account for 96 per cent of the market.[73]

The current reliance on a small number of crop varieties is not limited to fruit. Half of all the commercially produced broccoli in the US consists of the high-yielding Marathon variety.[74] In Greece, 95 per cent of the local varieties of wheat were abandoned in the period between the 1940s and the 1980s. In South Africa, most of the local varieties of sorghum have been displaced by imported American varieties.[75] Some 46,000 varieties of rice were cultivated in China during the 1940s, but by 1991 that figure had fallen to about 1,000, with 322 varieties planted over large areas. The same is true of wheat — while more than 13,000 varieties were planted in China during the 1940s, that number had declined to 500-600 by the 1990s, with only 331 planted widely.[76]

Similar trends are evident in animal husbandry. A small number of high-performance breeds have spread throughout the world since the mid-twentieth century, in many cases replacing local breeds. Most chickens produced in the US come from one variety — the Cornish cross. Over 99 per cent of turkeys are Broad-Breasted Whites.[77] While the developing world has until recently preserved a large number of indigenous breeds, an increasing number of breeds are now at risk.[78] For instance, of the 14 local pig breeds in Vietnam, five breeds are considered vulnerable, two are in a critical state, and three are at risk of extinction.

Currently, indigenous breeds constitute only 26 per cent of the country's pig population.[79] Many of the livestock breeds that are at risk of extinction are indigenous breeds that are well adapted to local conditions and are an important part of agricultural and pastoral traditions. Local breeds tend to be less costly to raise than exotic breeds, as well as having better abilities to survive and reproduce in harsh climates (which could become harsher due to climate change).[80]

The decline in diversity on farms — both in terms of crop and animal species and varietal diversity — has been most pronounced in developed countries where highly intensive agricultural systems predominate. One hundred years ago, a typical farm in the midwestern US state of Iowa integrated livestock such as cattle, pigs and chickens with a variety of crops such as maize,[81] wheat, oats, potatoes, hay, apples, cherries, plums, grapes and pears. Today, just two crops predominate: maize and soybeans.[82] These are the two most widely planted crops in the US, together occupying more than half of the American field crop area — 30 per cent in the case of maize, and 24 per cent in the case of soybeans.[83] Ironically, most of the US maize crop does not even directly feed people — instead it is used mainly for biofuels (40 per cent) and animal feed (36 per cent), with much of the remainder exported. Of the small fraction of the American maize crop that does feed American people, much of that is used to produce high-fructose corn syrup.[84]

In developing countries there is still a high level of diversity in smallholder agriculture.[85] While global figures are lacking on the extent of existing diversity on farms, the overall consensus is that crop diversity has been declining in recent decades.[86] Quantifying the number of crop species and varieties that have already been lost is difficult,[87] and even if varieties have been preserved in gene banks, they may no longer be cultivated by farmers.[88] Nonetheless, it is estimated that 21 per cent of all plant species worldwide are currently threatened with extinction, including food crops.[89] For animal breeds, there appears to be somewhat more available data, although even that is far from complete. Some 17 per cent of all animal breeds (a total of 1,458 breeds) are at risk of extinction, and 7 per cent have already disappeared. However, the true figures are likely much higher than this, as the risk status of 58 per cent of breeds is unknown.[90]

Factors behind the threat to agricultural biodiversity

Simplification of agricultural systems

The main reason for the loss of biodiversity on the farm is the simplification and standardisation of agricultural systems worldwide, whether in terms of cropping systems, crop species, varieties or the separation of livestock from arable farming. As one author observes, "Modern, industrial, scientific farming, which is characterized by monocropping, mechanization, hybrids, the use of fertilizers and pesticides, and capital intensiveness, has brought about a level of standardization into agriculture that is without historical precedent."[91] In developed countries as well as major agricultural exporters such as Brazil and Argentina, the spread of industrial agriculture has favoured large-scale monocultures of genetically uniform crops over diversified cropping systems.

In developing countries, the shift from traditional production systems based on farmers' varieties to modern production systems based on a far smaller number of hybrid varieties has also led to declining levels of diversity on the farm.[92] Much of this is a consequence of the Green Revolution, which involved the widespread dissemination of higher yielding crop varieties. While this enabled food supplies to keep pace with rapid population growth, lowering food prices, raising the health status of around 40 million preschool children[93] and potentially averting widespread famines according to many analysts,[94] it did have negative consequences for crop diversity and for the health and resilience of agroecosystems (discussed further later in this paper).

Commercial imperatives

One key driver of the uniformity that characterises modern crops and farming systems is the commercial imperative to maximise profits in a competitive marketplace. Corporate food retailer demands for standardisation in shipping, packaging and display put a premium on produce that is uniform in size, shape, colour and appearance. Producers are under pressure to focus on a small number of crop varieties that meet these criteria and to discard those that do not.[95] A related factor is the focus of many national governments on producing for export markets, as agriculture is a key economic sector and governments want to boost foreign exchange and trade.

Rice terraces in Bali, Indonesia (Pondspider)

Modern plant breeding

Although modern plant breeding has led to higher yields, it has also been instrumental in the simplification of agricultural systems. As Vigoroux et al. note, "the advancement of agriculture industrialization led breeders to concentrate on a few genotypes and to the development of improved and hybrid varieties. This approach led to standardization of the diversity in farmers' fields."[96] The authors also note that high-yielding crop varieties were bred to have a high harvest index (the ratio of grain weight to total biomass weight), to respond well to agrochemical inputs and to maximise the absorption of water and nutrients. The result was significant growth in agricultural productivity, but at the cost of diversity, since modern hybrids are more genetically uniform than traditional varieties. As farmers all over the world have adopted high-yielding varieties on their lands, in many cases they have not maintained their traditional varieties, despite the fact that they are rich in genetic diversity and possess many valuable qualities.[97]

Modern cropping systems

Cropping systems associated with modern agriculture have been as important as plant breeding in fostering uniformity. Much of the food produced today is grown in monocultures — vast fields of a single crop — that are conducive to mechanised planting and harvesting, while meeting imperatives to maximise profits in competitive markets. While all of agriculture can be considered a simplification compared to the profuse vegetation of an unmanaged landscape, modern agriculture is truly a radical simplification.[98] Simplification is also a planned outcome. As Frison et al. observe:

> Modern, intensive agriculture reduces agricultural biodiversity. In fact, it is predicated on such a reduction. Farms specialize in livestock or crops, reducing the number of species; fields are enlarged, reducing the extent of field margins and hedgerows; soil amendments enhance the uniformity of soils; and monocultures of genetically uniform individuals tend to dominate.[99]

Agricultural policies and programmes

Since the Green Revolution in the 1960s, agricultural policies and programmes in many countries have encouraged farmers to adopt monocultures of high-yielding varieties through subsidies for inputs such as seeds, fertiliser and irrigation.[100] For instance, in Rwanda, government policy encourages the use of monocultures of maize and other crops together with land consolidation and the use of subsidised inputs, while discouraging traditional intercropping systems.[101] Government ethanol initiatives in the US have provided increased incentives to plant maize, which in turn has led many farmers to discard formerly extensive crop rotation practices.[102] In Zambia, the two major programmes which account for the bulk of the agriculture budget — the Food Reserve Agency and the Farmer Input Support Programme — have focused on maize, which encourages farmers to do the same.[103] In the Khorezm region of Uzbekistan, a state procurement programme has resulted in 70 per cent of the

Many crops are grown in monocultures such as this soybean field (by Pixabay https://pixabay.com/photo-1610754/)

land area being planted to just two crops: winter wheat and cotton.[104] One key reason for the narrow approaches evident in agricultural policies and programmes is the way separate departments operate in their individual 'silos', leading to a lack of coordination and coherence among different ministries such as agriculture, environment and health.

Market concentration

One factor which both reflects and exacerbates the loss of agrobiodiversity is the dominance of the global seed market by a small number of private firms. Ten multinational companies control two-thirds of the seed market worldwide.[105] Moreover, those companies focus on major crops in order to deliver high returns on investment within a short time frame. Due to the lower license fees for wheat, it receives less attention from breeders than the other two major crops: rice and maize.[106]

Governments around the world often reinforce the dominance of multinational companies in the seed sector, while penalising the efforts of farmers to save, reuse, improve, exchange and sell their own seed. For instance, extension services in Zimbabwe and other African countries advise farmers to purchase certified hybrid seed maize and to discard saved seed, which they view as backward or of poor quality. This means that market-oriented farmers especially have to buy seed every year as most hybrid seeds cannot be saved and resown. Farmers are even being sued for patent infringement when they do.[107] Farmers' informal seed systems are often not recognised in national policy or law, nor provided any public support, in spite of their vital role in ensuring access to seeds for poor farmers and sustaining agrobiodiversity and resilient crops. Harmonisation processes currently underway in the African Regional Intellectual Property Organisation (ARIPO) favour the interests of multinational seed companies while undermining the ability of farmers to freely use, exchange and sell their saved seed.[108]

Other factors

There are many other factors promoting modern crop varieties and a few crop species and animal breeds at the expense of more diverse agricultural systems. These include: i) research and extension systems that promote a small number of modern crop varieties and animal breeds; ii) subsidies for modern varieties and inputs that lower the cost of production compared to traditional varieties produced through biodiverse farming; iii) intellectual property rights regimes that protect modern varieties and the absence of similar regimes to protect farmers' rights over their traditional varieties; iv) lack of markets for local varieties due to corporate advertising and changing consumer preferences in favour of foods such as pasta, white rice, white bread etc., which may be more convenient to prepare but are less nutritious than traditional foods (Box 2); v) weakening of traditional cultural values that promote production and consumption of diverse crops and animal breeds; and vi) rapid erosion of local knowledge and skills pertaining to diverse crop varieties.[109]

Box 2. Fort Portal, Uganda — losing diversity, value, nutrition and soil fertility

Thanks to fertile soils and favourable weather, Fort Portal is a food basket for the capital of Kampala and the region as a whole — as well as neighbouring countries like Rwanda, Sudan, Kenya and DRC. However, little economic value is retained locally, as the food processing sector is underdeveloped and large quantities of unprocessed food are shipped out of the area. This also impoverishes local soils because the organic matter and nutrients contained in crop residues are not returned to the soil.

Many rural households are poor and under tremendous pressure to generate cash to cover childrens' school fees, medical expenses and other basic needs, all the more so because large families are the norm. Due to economic pressures, it is common for farmers to sell a large proportion of what they produce rather than consuming it in the household. This is exacerbated by the lack of proper post-harvest storage facilities. Traditional methods of crop storage such as the use of plant leaves to prevent pest infestations have been lost.

Changes in cropping patterns have also undermined nutrition and food security. As one farmer observed, "People have changed the crops they grow. They used to practise rotational crops where you have a garden of groundnut, beans, potatoes, cassava and matoke (a type of plaintain). But recently the food people grow has changed because they have gone commercial. These days they are growing only maize and matoke. And since they earn a lot of money from them, they neglect other crops. In our early days they used to grow a variety of foods that could take a family throughout the year, but maize is a seasonal crop. You grow, harvest, it goes… and families are left without food. At times you find conflict between the woman and man because the man wants to sell everything without leaving a single sack for the family and they end up going hungry." The focus on growing commercial crops like maize and matoke has coincided with a decline in diversity on the farm and on the plate. Even where farmers are still growing a variety of crops, they often sell most of them to meet urgent needs for cash.

Diets in the region are high in starchy foods like matoke, maize, cassava, potatoes and sweet potatoes, but low in protein. Traditional crops in Uganda included a wide variety of green vegetables, but these are increasingly being left out of local diets and this is one of the causes of high levels of malnutrition in the country. For instance, 41 per cent of the children in the Tooro subregion where Fort Portal is situated are stunted (too short for their age), the highest incidence in the country.[110] Although millets are a much better source of protein than matoke or rice, their consumption is declining, partly due to the longer preparation time required. Increased consumption of processed foods and easily prepared foods like white rice is another reason for a decline in consumption of traditional foods like millet, which are more nutritious.

Sources: Vorley and Boerwinkel (2016) and interviews conducted with farmers and participants in the People's Summit on Food held in Fort Portal, Uganda in April 2016

Consequences of the loss of diversity

The increasing prevalence of monocultures and a small number of genetically uniform crop varieties has contributed to higher productivity, but this is at the cost of agroecosystem vulnerability to pests and diseases, and heavy applications of fertilisers and pesticides — which have generated serious pollution and public health problems.[111] As agricultural landscapes are simplified, pest pressure and insecticide use increase.[112] The heavy use of pesticides may kill off natural predators as well as triggering increased resistance on the part of weeds, pests, viruses, fungi and bacteria, thereby sparking a vicious cycle of increased chemical applications and greater resistance.[113] Cases of herbicide-resistant weeds have been reported in 69 countries, affecting 91 different crops.[114]

The most striking example of crop vulnerability due to genetic uniformity is the banana, the most popular and valuable fruit in the world. Exports alone are worth some US$7 billion. Although over 1,000 varieties of banana exist,

just one variety — the Cavendish — accounts for 95 per cent of banana exports.[115] This variety is popular with consumers and can survive weeks of shipping, unlike most other varieties. Unfortunately, the Cavendish variety is susceptible to the TR4 virus, which has ravaged banana plantations in much of Southeast Asia and now threatens plantations worldwide. Since the Cavendish — like the tastier Gros Michel variety which preceded it — is grown in large monocultures, it is particularly vulnerable to the spread of disease. The lucrative global banana trade, as well as the livelihoods of millions of smallholder farmers who grow bananas, are at risk as a result.[116]

Bananas are by no means the only vulnerable crop. An estimated 80-90 per cent of wheat varieties grown worldwide are susceptible to the Ug99 race of stem rust, which is considered to be a significant threat to global wheat production.[117] An outbreak of army worm in Zambia at the end of 2016 affected 223,000 ha of maize (20 per cent of the maize crop), forcing the government to invest over USD 3 million in pest control.[118] There are many other examples of the vulnerability of genetically uniform monocultures, such as the southern leaf blight epidemic that ravaged the U.S. corn crop in the early 1970s[119] and the Tungo rice epidemic that affected the rice crop in Indonesia and the Philippines.[120] All of these pest and disease outbreaks brought heavy economic losses and widespread suffering in their wake.

In the animal husbandry sector, the trend in many countries towards large-scale, intensive production facilities in CAFOs (concentrated animal feeding operations) is exacerbating risks of disease and undermining genetic diversity in livestock populations. While significant genetic diversity exists among small-scale livestock populations, animal breeding for CAFOs prioritises genetic uniformity to facilitate industrial meat processing and homogeneity of products.[121] Diseases such as foot-and-mouth disease and avian influenza have spread swiftly in the intensive, high-density operations favoured by commercial farming. Epidemics have been particularly disastrous among genetically uniform animal populations.[122] At the same time, the over-use of antibiotics in industrial animal production systems — partly as a way of dealing with the health problems of simplified, overcrowded and intensive production systems — has contributed to a global public health crisis of resistant strains of bacteria which cannot be dealt with effectively through the use of antibiotics.[123]

The decline of biodiverse traditional farming systems in favour of monocultures has led to a loss of traditional varieties which have contributed genes to many key traits in modern crops, such as higher yields, resilience in the face of biotic and abiotic stresses, and tolerance of poor soils, drought and low temperatures. Traditional varieties are often more resilient to drought and other environmental stresses than their modern equivalents — for instance, landrace maize survived the big spring drought in Southwest China in 2010 while hybrid maize did not.[124] A decline in crop diversity means that this genetic material may no longer be available to farmers and plant breeders in the future. Loss of genetic diversity can also interfere with evolutionary processes that could lead to the emergence of new genes and gene combinations and respond to environmental change.[125] The capacity of agriculture to adapt to climate change and other variables depends on the maintenance of a diversity of cropping systems, crop varieties and animal breeds. In light of the unpredictable nature of future stresses, the implications of the loss of agricultural diversity could be enormous.[126]

DIVERSE, HIGH-QUALITY DIETS FOR HUMAN HEALTH

The importance of dietary diversity and quality

Just as there is robust evidence for the importance of agricultural biodiversity and the need to preserve it, there is a strong consensus among nutritionists that dietary diversity is a key element of healthy, high-quality diets. Dietary diversity is the most important factor in providing the spectrum of micronutrients essential for human health.[127] Dietary diversity is also critical in maintaining a healthy gut microbiome, which is an important aspect of overall health.[128] Most food-based dietary guidelines (Box 3) recommend increasing the variety of foods both within and across different food groups, because doing so helps to promote good health and ensure an adequate intake of essential nutrients.[129]

Box 3. Food-based dietary guidelines

Dietary guidelines arose from the need for simple and practical rubrics to enable people to choose healthy diets, prevent disease and to guide countries in the development of food, health and agricultural policies. According to the FAO, these guidelines:

> "provide context-specific advice and principles on healthy diets and lifestyles, which are rooted on sound evidence, and respond to a country's public health and nutrition priorities, food production and consumption patterns, sociocultural influences, food composition data, and accessibility, among other factors."[130]

The importance of dietary diversity is widely recognised. However, it is not enough that diets be diverse; they also need to be healthy and of high quality. What does a healthy and high-quality diet look like? While there is no universal standard, there is general agreement that healthy and high-quality diets should provide sufficient energy and all the essential nutrients and non-nutritive factors, like fibre, that people require. Such diets should be safe and free from contaminants. In addition, the Global Panel on Agriculture and Food Systems for Nutrition argues that high-quality diets are those that "reduce all forms of malnutrition, promote health and are produced sustainably, i.e. without undermining the environmental basis to generate high-quality diets for future generations").[131, 132]

The precise ingredients of a healthy diet vary according to an individual's requirements (e.g. age, gender and level of physical activity), dietary preferences, cultural setting, as well as what foods are available locally. However, according to the World Health Organization, certain basic principles are widely applicable. A healthy diet includes ample quantities of fruits, vegetables, legumes, nuts, seeds and whole grains, with limited consumption of salt, free sugars, sugary snacks and beverages and ultra-processed foods. Industrial trans fats should be avoided, and where possible, saturated fats should be replaced with unsaturated fats.[133]

Quality and diverse diets at risk

Today approximately 3 billion people have low-quality diets.[134] Low levels of dietary diversity and quality are a serious problem among many poor people in developing countries, whose diets tend to consist mainly of starchy staples, with few animal products and insufficient amounts of fresh vegetables and fruits. Such diets are often low in a range of micronutrients; those that are present may not be in a form that is easily absorbed, leading to malnutrition.[135] Low levels of dietary diversity are also associated with stunting in children.[136] The measurement of dietary diversity is discussed in Box 4.

Box 4. How to measure dietary diversity?

Dietary diversity is a useful proxy indicator for nutrient adequacy[137] and dietary quality.[138] It is measured by recording the number of foods or food groups that an individual consumes within a 24-hour period. It is a qualitative means of assessing the access that an individual or household has to a variety of foods. There are indicators for individuals and households.[139]

For example, indicators have been developed and validated to assess dietary diversity in young children aged 6-23 months. These are based on seven food groups: grains, roots and tubers; legumes and nuts; dairy products (milk, yogurt, cheese); flesh foods (meat, fish, poultry and liver/organ meats); eggs; vitamin-A rich fruits and vegetables; and other fruits and vegetables. The minimum threshold is attained when children consume foods from at least four groups in one day.[140]

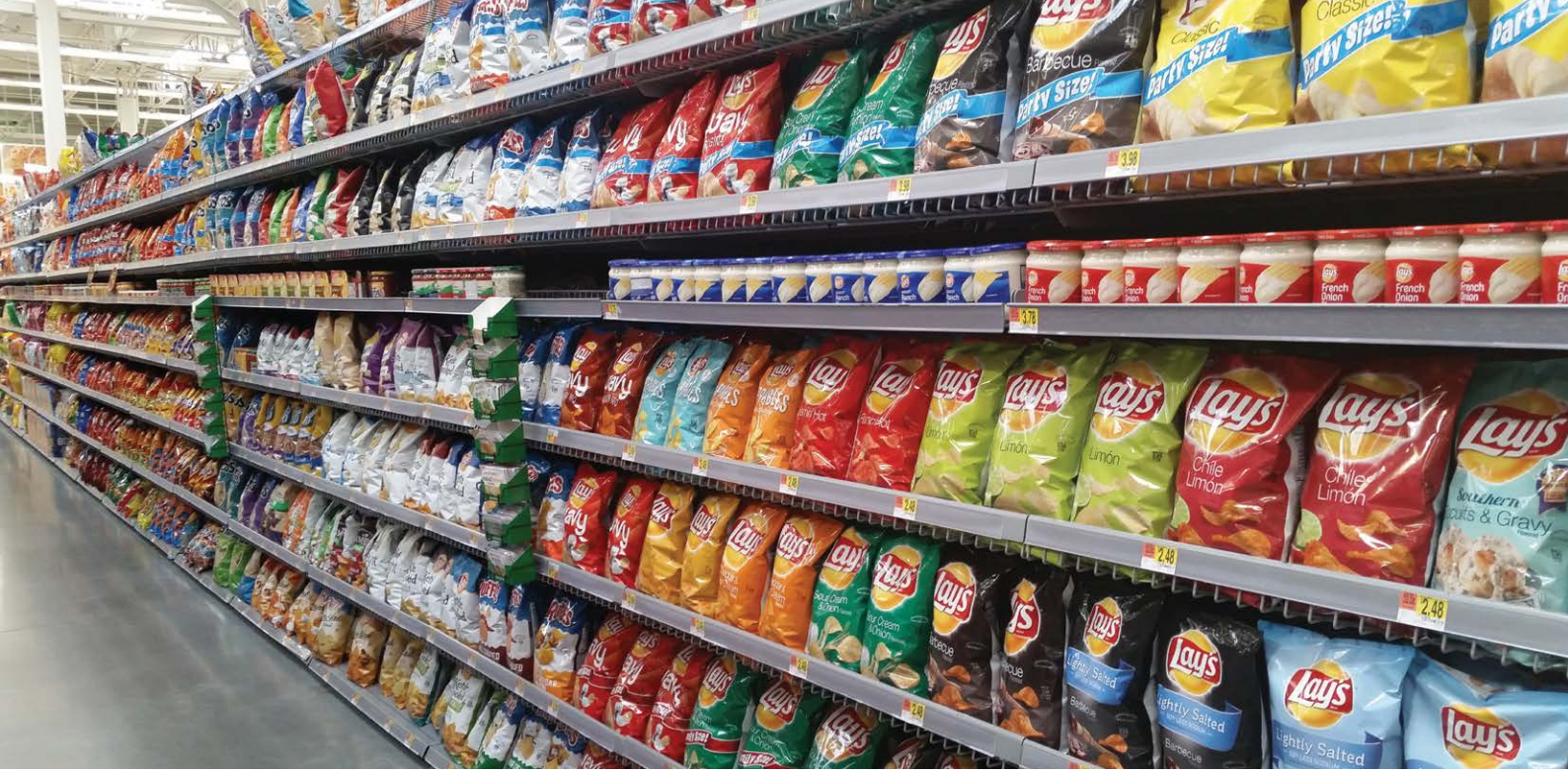
A new internationally accepted indicator has been developed by FAO — known as Minimum Dietary Diversity — Women (MDD-W) — as a simple proxy for the micronutrient adequacy of women's diets.[141] It is based on ten food groups. Adequate diversity is achieved when women consume foods from at least five groups in 24 hours.[142] The dietary diversity measures that have been developed for women and children are considered to be good indicators of diet quality, as they are closely associated with micronutrient adequacy — a key aspect of diet quality. The household-level indicator — which is based on 12 food groups — is a useful indicator of food security.[143]

The Sustainable Diets for All programme has used food diaries in Uganda and Indonesia to gather information on dietary diversity, food choices and sources of food. These diaries are usually recorded by participants themselves rather than by researchers. In Uganda, food diaries showed that rural households are increasingly reliant on the market for their food. In Indonesia, food diaries by female factor workers revealed the key role played by informal food markets in meeting their nutritional needs.[144]

However, poor quality diets and diets low in diversity are not simply a problem of poverty — they are an issue facing all countries and all strata of society, whether low, medium or high-income. The Global Panel on Agriculture and Food Systems for Nutrition summarises the global data as follows:

> Infants are not being breastfed as formula sales soar; young children, adolescents and women are existing on monotonous, starch-based diets with little diversity and inadequate animal source foods, increasingly supplemented by ultra-processed foods, while others consume too much red meat, saturated and trans fats, soda and ultra-processed foods and soft drinks. Although fruit intake has been increasing, people are not consuming sufficient amounts of fruits and vegetable intake is declining.[145]

The world is in the midst of a major shift in dietary patterns, often termed the 'global dietary transition' or 'global nutrition transition'. The nutrition transition is occurring fastest in urban areas of developing countries, although at different rates in different regions and socioeconomic groups.[146] Characteristics of the dietary transition are higher intakes of refined grains, sugar and animal products, coinciding with increased consumption of processed foods and prepared meals; higher frequency of eating outside the home — particularly in fast food restaurants; and increased intake of edible oils and sugar-sweetened beverages.[147] The US has led the way in the dietary transition, with rising obesity levels following in its wake.[148] Today, ultra-processed foods (Box 5) account for nearly 60 per cent of calories and 90 per cent of added sugars in American diets.[149] Other countries are tending to follow the same path of rising consumption of ultra-processed foods, with negative consequences for human health.



Supermarket aisle with ultra-processed foods (Image by Pixabay https://pixabay.com/photo-2179178/

Box 5. What is ultra-processed food?

For most of human history, food processing has had positive associations with health and well-being. The use of fire and salt to prepare and cook food, as well as methods of food preservation such as fermentation and smoking, are examples of processing that have facilitated the development of human civilisation.[150] However, industrialisation has transformed the nature and extent of food processing.

The Pan American Health Organization describes ultra-processed foods as "industrial formulations manufactured from substances derived from foods or synthesized from other organic sources. In their current forms, they are inventions of modern industrial food science and technology. Most of these products contain little or no whole food. They are ready-to-consume or ready-to-heat, and thus require little or no culinary preparation."[151] Some of the ingredients in ultra-processed products are derived from foods, such as starches, fats, oils and sugar. Others are made through the further processing of food ingredients, such as the hydrolysis of proteins and the hydrogenation of oils (which creates trans fats). Many of the constituents of ultra-processed products are additives like emulsifiers, colours, flavours, preservatives, stabilisers and sweeteners. Ultra-processed products may be fortified with synthetic micronutrients.

Some examples of ultra-processed products are chips, candies, margarine, carbonated beverages and energy drinks, packaged breads, pastries, cakes, preserves, sweetened breakfast cereals, energy bars, ice cream, fruit yogurt drinks and infant formulas. Ultra-processed products also include ready-to-heat and ready-to-consume products such as burgers and hot dogs, French fries, fish nuggets, as well as packaged soups, noodles and desserts. Ultra-processing "creates attractive, hyper-palatable, cheap, ready-to-consume food products that are characteristically energy-dense, fatty, sugary or salty and generally obesogenic".[152] Ultra-processed foods are problematic for a number of reasons. They are harmful to human health in that they are intensely palatable, conducive to snacking, of low nutritional value and even quasi-addictive.[153] Where they displace healthier items, they can also be socially, culturally, economically and environmentally destructive.[154]

Ultra-processed products are increasingly prevalent in the global food system.[155] While purchases of these products have levelled off in high-income countries, they are growing rapidly in low and middle-income countries. In East and Southeast Asia, for instance, sales of ultra-processed products are forecast to reach the levels of high-income countries by 2035. Growth has also been rapid in African countries. In surveys conducted among the poorest urban residents in six African countries, 31 per cent of expenditures on food are on highly processed foods. For

higher income groups in these same urban areas, that figure is 65 per cent.[156] Studies of foods purchased by households in Brazil and other countries demonstrate that ultra-processed products are displacing healthy and diverse foods such as rice, beans, milk, cassava, vegetables and fruits in people's diets. This is occurring partly because dietary patterns are shifting away from regular freshly prepared meals towards a higher frequency of snacking on energy-dense foods high in salt, sugar and fat, the driving factors of which are discussed below.[157]

Health consequences of current dietary trends

The global dietary transition has had serious health consequences. Higher consumption of energy-dense, nutrient-poor foods combined with lower levels of physical activity are leading to epidemic levels of overweight and obesity, as well as other diet-related noncommunicable diseases (NCDs) such as diabetes, metabolic disorders, hypertension, coronary heart disease and cancer.[158] In this context, over- and undernutrition often coincide, even within the same families.[159] Rates of overweight and obesity are increasing rapidly throughout the globe, both in rural and urban areas, including in the poorest countries of Sub-Saharan Africa and South Asia.[160] It is estimated that obesity will cost at least $750 billion globally by 2025.[161]

Diet-related health problems now exceed those stemming from undernutrition in virtually every part of the world.[162] NCDs are the now the leading cause of death worldwide, accounting for 38 million (68%) of the 56 million deaths in 2012. In low- and middle-income countries, NCDs are now responsible for more deaths than infectious diseases. In fact, nearly three-quarters of all deaths from NCDs occur in low- and middle-income countries.[163] NCDs do not simply lead to increased mortality rates — they cause tremendous hardship for the living as well, while contributing to escalating health care costs. For instance, type 2 diabetes alone affects one in twelve people worldwide. An estimated $673 billion — or 12 per cent of global health care costs — is spent annually on diabetes.[164] In the absence of effective measures to address them, the "social and economic costs of NCDs will continue to grow and overwhelm the capacity of countries to address them".[165] Based on present trends, it is estimated that NCDs will cause cumulative economic losses of US$7 trillion in low- and middle-income countries between 2011 and 2025.[166]

Factors behind the prevalence of low-quality diets

What factors are contributing to the prevalence of low-quality diets among large segments of the world's population, particularly in developing countries? In addition to the shifts in dietary patterns described above and in the next section, the first contributing factor is poverty and the fact that the incomes of many people are too low to access an adequate variety of foods on a regular basis. Availability, accessibility and affordability of diverse and high-quality foods are often limited in impoverished rural and urban areas.[167] Increases in food prices and greater price volatility — particularly since the food crisis of 2008-11 — have made healthy, diverse foods too expensive for many low-income consumers, and have encouraged many people to shift their food consumption more towards ultra-processed and fast foods.[168] At the same time, access to land and natural resources is declining for many poor people as a result of urbanisation, population growth and changes in land use associated with the shift from traditional farming systems to large-scale monocultures and plantations, as well as forestry, mining, dams, infrastructure development and other capital-intensive operations.[169] Other factors include the dietary ramifications of the Green Revolution; the narrow focus of agricultural policies and research; and the power of the food industry to shape people's tastes.

Rising incomes, urbanisation and globalisation

Coinciding with low-quality diets and low levels of dietary diversity are the major shifts in dietary patterns that are occurring around the world, driven by rising incomes, rapid urbanisation, changing lifestyles and globalisation. These shifts are having mixed and often contradictory effects on diets. For example, as incomes rise, the consumption of healthy foods such as fruits, seafood, milk and polyunsaturated fats tends to increase, but so does consumption of unhealthy foods such as sugary beverages,

refined flour, processed meat and sodium. Meanwhile, vegetable consumption tends to decrease (though it is increasing in some populations), as does fibre. Thus rising incomes are no guarantee of diverse, high-quality diets, although they do contribute in some respects.[170] Education and the availability of healthy, good quality foods are both important to ensure that higher incomes lead to better diets.

Meanwhile, rapid urbanisation and accompanying changes in lifestyles are having far-reaching impacts on diets worldwide. On the one hand, urban populations have greater access to a variety of foods year-round than people in rural areas, including fresh produce (if they can afford it). On the other hand, they also have greater access to energy-dense, nutrient-poor foods and are more vulnerable to changes in food prices.[171] As populations urbanise and as a larger proportion of women enter the workforce, time for cooking and shopping decreases, which has led to the rise in demand for fast foods and pre-prepared foods.[172] Another factor is that many of the urban poor in developing countries have limited cooking facilities, and often rely heavily on food purchased from street vendors.[173] Increased demand for food outside the home is associated with the risk of low micronutrient and high fat intakes,[174] although research with female factory workers in Indonesia has shown that it is possible to obtain a diverse, affordable diet with street food.[175] Overall, urbanisation is associated with lower levels of malnutrition compared to rural areas, but higher rates of obesity and chronic diseases.[176,177] In many rural areas, diets are shifting away from more diverse and nutritious traditional foods, due both to changes in culture as people become more westernised, as well as to the increased availability of cheap processed foods (e.g. cheap rice-based snacks produced using subsidised rice from the Public Distribution System in India).[178] Another factor behind dietary shifts in farming households is changes in livelihood strategies and the intergenerational loss of knowledge and informal training opportunities that one needs to be a successful subsistence producer.[179]

Policies and processes of globalisation have had a profound impact on food systems and diets around the world. On the one hand, they have contributed to dietary diversity by making a wider variety of foods available than had previously existed in many contexts. On the other hand, they have increased the availability and consumption of ultra-processed foods. One study found that low- and middle-income countries that have a free trade agreement with the United States have a 63 per cent higher rate of soft drink consumption per capita than countries which do not.[180] Trade liberalisation policies have been a key factor contributing to the "nutrition transition", which is associated with growing incidence of obesity and NCDs.[181]

The dietary ramifications of the Green Revolution

The mixed effects of the current dietary transition were also characteristic of the Green Revolution in agriculture, which focused on improvements to the main cereal crops such as rice, wheat and maize.[182] While the Green Revolution was beneficial in terms of raising productivity and lowering food prices, it also had some serious unintended consequences for diets and crop diversity in the developing world. The shift away from traditional mixed cropping systems towards cereal monocultures has had the effect of limiting food-crop diversity and appears to be contributing to micronutrient deficiencies.[183]

By contrast, diverse cropping systems tend to provide more micronutrient-rich food crops such as legumes, fruits and vegetables, which may no longer be available or affordable to poor farmers. Thus the shift from traditional mixed agricultural systems to ones focused on cereal production has in some cases reduced micronutrient availability and led to a rise in micronutrient malnutrition (e.g., deficiencies of iron, zinc and vitamin A) in rural people reliant on these agricultural systems for their livelihoods.[184] At the same time, many traditional food crops and the agronomic systems of which they were a part have been displaced or neglected. This has also had deleterious consequences for diets in rural areas, because many traditional crops such as millet and

Maize field in Zambia (Andrew Chifire)

pulses are richer in nutrients than the high-yielding varieties of rice and maize that replaced them.[185, 186]

The narrow focus of agricultural policies and research

Current agricultural policies tend to focus on the production of a small number of staple crops with little regard to the delivery of nutrients or the need to promote diverse diets (see Box 6 for a Zambian example).[187] Food security is often equated with producing a sufficient quantity of the key staple crops. Government priorities are clearly evident from budgetary allocations, even if rhetorical attention is given to other areas.

Similarly, agronomic research on staple crops such as rice has focused on yield, with much less attention to the nutrient

Box 6. Mono-diets from monocrops — the case of Zambia

In 2017, Zambian farmers harvested a bumper crop of maize. Although maize is Zambia's most important crop and the primary source of calories for rural and urban dwellers alike, a bumper harvest will do little to alleviate the under-nourishment that affects 48 per cent of the population in Zambia.

Some 40 per cent of Zambian children under the age of five are stunted (too short for their age and often with reduced cognitive capacities), while 23 per cent of Zambian women are overweight or obese. All these issues are a result of poor diets, high in starch and calories but low in nutrient-rich fruit and vegetables. Incidence of chronic disease like diabetes and hypertension is high. The double burden of malnutrition and obesity, together with high levels of chronic disease, exact a heavy toll in terms of health costs as well as lost productivity and potential of the population. The government of Zambia estimates that economic losses from stunting alone will be US$18 billion in the period between 2017-2026 if the current situation continues.[188]

At the heart of the problem is the predominance of maize in the Zambian diet and agricultural system. Native to Mesoamerica, maize was introduced to Zambia and other African countries during the 1600s, and its promotion by the British colonial administration gradually led it to eclipse staple crops such as millet and sorghum, which though less productive, are more nutritious and better suited to the ecological conditions of the country. This has had a negative impact on diets — millet in particular is far more nutritious than maize.

The overdependence on this monoculture has also led to a loss of resilience on Zambian farms. This was demonstrated by a serious outbreak of army worm at the end of 2016, which affected the maize crop more than traditional staple crops. At the same time, nutritious indigenous vegetables are increasingly being neglected in favour of a small number of introduced varieties. Thus one of the keys to improving Zambian diets is to promote more diverse agricultural production, which in turn requires supportive policies, markets and infrastructure.

Sources: Chilufya (2016); Mwanamwenge and Harris (2017)

Plates from vegetarian restaurant in Bandung, Indonesia (Silvana Paath)

contents of different crops and varieties.[189] The primary metrics for evaluating the success of agricultural systems have been crop yields, economic output and cost-benefit ratios — yet these metrics do not capture the diversity of nutrients that are essential for human health.[190] The emphasis is primarily on cereals which provide energy and protein, with much less attention to fruits and vegetables, which are the richest sources of many micronutrients.[191] Even when non-staple crops are targeted for research and improvement, the focus tends to be on individual crops rather than the promotion of diverse production systems.

At the same time, food-based interventions in developing countries, such as bio-fortification, have tended to focus on single nutrients such as iodine or vitamin A.[192] The problem with this approach is that nutrient deficiencies usually do not occur in isolation.[193] Unfortunately, there has been less attention to interventions that provide a range of nutrients. Diversifying diets to include a variety of high-quality and nutritious foods — including foods derived from traditional crop varieties — can reduce micronutrient and other deficiencies by providing a full spectrum of nutrients throughout the year.[194]

The power of the food industry to shape consumer tastes

Perhaps the most important factor of all in influencing dietary diversity and the quality of diets is the pervasive influence of the food industry. The global retail food industry is worth approximately $4 trillion annually,[195] and the leading food product manufacturers are giant transnational corporations with annual revenues on a par with the gross national products of middle-income countries.[196] These companies spend enormous amounts of money on marketing and advertising their products, the most profitable of which tend to be ultra-processed foods — due to their long shelf life, low production costs and high retail value. Their sales strategies are designed to overcome any reluctance that a person may have to buy their products and are based on the latest scientific knowledge of behaviour motivation.[197] Much food industry advertising is directed towards children and adolescents, particularly for unhealthy snacks, sodas, cereals, candies and other foods high in salt, sugar and fat. These foods are portrayed as being fun, tasty and even empowering.[198]

In a world where consumers in many countries have a large number of choices at their disposal, the food industry is an intensely competitive one, and food companies invest significant resources to develop and market products that will sell. They must compete fiercely for 'stomach-share' — as the industry terms it. They are also beholden to shareholders. These factors ensure that food companies are preoccupied with profits and beating the competition rather than the health or nutrition of their products. The foods which are most profitable for the food industry and which they most vigorously promote are often those that are high in salt, sugar and fat. Salt, sugar and fat are cheap and interchangeable, allowing food companies to avoid using more expensive ingredients like herbs and spices. Food companies are well aware of the appeal of these ingredients and actively engineer combinations of them to maximise the allure of their products.[199]

Changes in the food retail sector have also had a profound influence on food consumption patterns. While there is enormous diversity in food retail systems, distinctions can be made between 'traditional' and 'modern' systems. Many communities in rural and low-income urban areas still rely heavily on local markets to access fruits, vegetables, staples

and livestock products.[200] At the same time, the modern food retail sector — which includes supermarkets and convenience stores — is playing an increasingly important role in shaping access to food in the urban areas of many low- and middle-income countries, and in fact is gradually replacing traditional retail outlets such as local markets and small independent grocery shops.[201]

This trend has important and often contradictory implications for dietary diversity and quality. On the one hand, the rise of the modern food retail sector can make fresh foods such as dairy products, fruit and vegetables widely available while improving food quality and safety. But on the other it also facilitates the increased marketing and consumption of ultra-processed foods.[202] Much of this influence is subtle, such as the placement of items in supermarkets. Fresh fruit and vegetables are often situated on the far side of stores, with the most profitable ultra-processed items — which are also the least healthy — placed at eye level in the middle aisles. Healthier staples such as whole wheat flour and rolled oats are relegated to the lower shelves. Soda and candy are enticingly placed right by the checkout lines to tempt people as they wait in line.[203]

The food industry contends that food choices are a matter of personal responsibility, but the current food environment in many countries often makes it difficult to make healthy food choices.[204] In low-income urban areas, cheap fast foods are often more readily available than healthy items in supermarkets and restaurants. Furthermore, healthy foods like fruit and vegetables often cost more than unhealthy ultra-processed foods, which constrains the choices of low-income consumers. This trend has become more pronounced over the last 30-40 years, as ultra-processed foods have become cheaper relative to fruits and vegetables.[205]
The overall effect is that in developing countries, ultra-processed foods and beverages are increasingly displacing foods prepared from unprocessed or minimally processed ingredients, with negative impacts on dietary diversity, quality and human health.[206]

THE RELATIONSHIP BETWEEN AGRICULTURAL BIODIVERSITY AND DIETARY DIVERSITY

Having discussed separately the importance of agricultural biodiversity and dietary diversity, and the reasons why both are at risk today, in this section we make the links between the two, mainly referring to the developing world. Diverse foods reach consumers in developing countries through three main pathways: 1) growing their own food and gathering wild foods; 2) buying foods from formal or informal markets (Box 8); and 3) exchanging food with relatives, neighbours or other community members.[207] Agriculture supplies the foods and ingredients that determine the diversity and quantity of foods available for human consumption. For farm households, agriculture also generates income that can be used to buy foods that are not produced on the farm. Where smallholders produce on a subsistence basis, there is likely to be a strong correlation between crop diversity and dietary diversity. However, farm households are generally not exclusively subsistence-oriented or market-oriented, but tend to produce agricultural products both for sale and for their own consumption.[208] Moreover, many rural people are net purchasers of food today, and many no longer work in agriculture.[209] These elements and their link to dietary diversity are explored in detail below.

Does diversity on the farm lead to diversity on the plate?

There is substantial evidence that diverse agricultural production contributes to dietary diversity among farm households in developing countries.[210] However, this relationship is complex and is mitigated by markets and other factors such as gender and control over resources (Box 7), wealth, cultural values and the existing degree of on-farm diversity. While diverse production systems should be encouraged — both for reasons of sustainability and dietary quality — other factors must be considered as well to ensure diverse and healthy food consumption. Hence, one cannot assume that diverse agricultural production automatically leads to diverse consumption. For instance, farmers may be growing a variety of crops but selling most of them to meet urgent needs for cash, as is the case with some farmers in Fort Portal, Uganda (see Box 2).

Box 7. The role of women in fostering diversity of food production and consumption

Gender and control over resources are particularly important in determining what crops are grown and whether diverse production contributes to more diverse diets. Women play key roles both as producers of food and also in purchasing food and preparing meals — key arenas where food choices play out. In the review cited above, the association between agricultural biodiversity and dietary diversity was stronger in female-headed households than in male-headed households. A study in Nepal found that when women had greater autonomy in production and working hours, maternal and children's dietary diversity improved.[211] There is also evidence that control of resources by women leads to greater allocations of household resources for food.[212] Conversely, where women lose control over land or other resources essential to agricultural production through an increase in cash cropping or other factors, it can lead to less diverse crop production and potentially lower dietary diversity as well.[213]

Smallholder farmer with pumpkins she harvested in her maize field in Chongwe, Zambia (Tsvangirayi Mukwazhi)

Most academic studies have found a positive association at the household level between the diversity of agricultural production and dietary diversity in agricultural households, although they differ on the magnitude of the association and the role of the market.[214] For instance, a review of 15 empirical studies in low- and middle-income countries analysed the relationship between agricultural biodiversity and market access and the diversity and quality of diets in agricultural households.[215] It found that agricultural biodiversity at the household level is positively associated with dietary diversity or dietary quality of both individuals and households in 14 out of 15 studies, irrespective of wealth or market access.

In terms of nutritional outcomes, the types of crops grown can make a big difference. In this sense, not all diversity is equal. The addition of one or more species such as pumpkin (high in vitamin A, zinc and certain amino acids) can make a big difference if it is providing nutrients not present in the other crops. Thus, even with the same total numbers of crops, differences in species compositions can significantly affect nutritional outcomes.[216]

The paradigm of nutrition-sensitive agriculture is helpful in connecting agrobiodiversity and dietary diversity, in that it addresses the relationship between agricultural production, human health and nutrition.[217] This paradigm puts dietary diversity and nutritious foods at the centre of agricultural development strategies. These strategies often include home vegetable gardens, small livestock rearing, fisheries, dairy development, biofortified crops and measures to improve food preparation, processing and storage. Promoting greater diversity of food production is one of the main ways that nutrition-sensitive agriculture can be implemented, which in turn can enhance dietary diversity by making a wider variety of crops and animal products available at the local level. [218]

Homestead food production (HFP) is one approach that has been shown to improve dietary diversity and nutrition. A review of HFP programmes carried out in 30,000 households in Bangladesh, Nepal, the Philippines and Cambodia found that they increased the year-round availability of micronutrient-rich foods for poor households, thereby improving the nutritional status of participants. Key to this was increasing the diversity of fruit and vegetable production at the household level, combined with greater production of animal-source foods such as meat, poultry and eggs. Integrating crops with animal husbandry led to better nutritional outcomes than growing plant source foods alone. Empowering women by making them HFP managers was another key feature of the programme's success, as was nutrition education.[219]

The role of markets

The relationship between production diversity and dietary diversity becomes even more complex when the role of the market is considered. Given that rural households are rarely totally self-sufficient, even in remote areas, markets often play an important role in dietary diversity. For instance, several studies indicate that higher levels of market access are associated with greater dietary diversity or quality.[220] Another factor is that many rural households have off-farm sources of income, either from local part-time work, or from remittances by family members living in other areas. This income may in turn be used to purchase food. Sibhatu et al. (2015) go even further to argue that access to markets and off-farm employment has larger effects on dietary diversity among smallholders than higher production diversity. Similarly, Snapp and Fisher (2015) found that income, market access, educational levels, and the presence of good storage facilities were even more important for dietary diversity than the diversity of crops grown on the farm.

The link between agricultural production, dietary diversity and improved nutritional outcomes also changes with economic development. As incomes rise, the market plays an increasingly important role in supplying people's dietary needs, as people purchase more food, and subsistence production and consumption decline.[221]

Markets are a double-edged sword when it comes to food diversity. They may foster greater diversity under certain circumstances and impede it under others. Unfortunately, there seem to be more examples of the latter than the former. Where commercial crop production eclipses traditional crop production, crop diversity — and potentially also nutrition — may suffer.[222] For instance, in south-central Mali, commercially valuable crops — cultivated by men and composed largely of exotic species — have replaced traditional crops previously cultivated by women (and see Box 2 for a Ugandan example).[223] The decline of traditional green leafy vegetables has implications for local diets as well as the preservation of agrobiodiversity. Other cases of markets impeding diversity include: the uniformity of form, appearance and varieties imposed by supermarkets; dealers who may not want to buy the many different kinds of maize or vegetables that farmers grow; and the fact that linkages to markets may reduce dietary diversity because of greater availability of cheap processed foods.

However, there are also cases where market linkages do support diverse agricultural production. In Benin, market participation is associated with greater on-farm diversity, facilitating the purchase and sale of diverse foods (although travel distance was also an important factor).[224] In the Central Mexican highlands, cultivating traditional maize varieties offers benefits to small- and medium-scale farmers, who take advantage of speciality markets to sell their products.[225] As Herforth (2010) notes, "viable markets for underutilized crops can sustain traditional food and traditional knowledge and provide the major motivation for farmers to produce those crops."[226] In the developing world, many of these markets are informal (Box 8).

Farmers' markets — which are thriving all over the world — enable farmers to sell more varieties than commercial processors would buy, while generating higher incomes from their produce. One study in Madison, Wisconsin found that a weekly farmers' market offered more than three times the number of distinct crop varieties than the city's supermarkets.[227] Farm-to-table restaurants also foster on-farm diversity. There are many such examples around the world. For instance, the NGO Farmers Friends operating in Guangxi province, China has set up eight organic restaurants linked with a network of 16 rural communities and cooperatives that supply the restaurants with pork, grains and a variety of vegetables. The stable market provided by the restaurants allows the villagers to grow a diversity of crops using agroecological methods.[228]

Investing in small and medium-sized enterprises (SMEs) is another means to foster diverse food production and consumption. For instance, the Hivos Food & Lifestyle Fund invests in food companies that promote diversified, healthy diets from local foods grown in a manner that supports biodiversity and improves soil health. One such company is *L'Atelier du Miel*, which produces 30 varieties of Lebanese honey in a biodiversity preserving manner by moving the beehives year-round, thereby following flowering seasons. Another company is Lady Bonin's Tea, which sources its premium quality teas from small organic farms in South Africa.[229]

Informal food vendors in Bandung, Indonesia (Kemal Jufri/Panos Pictures)

Box 8 — Informal food markets

The informal sector — defined as that portion of the economy which is not formally taxed, regulated or subject to government monitoring — supports some of the world's most vulnerable people, such as women, youth and the rural poor.[230] In Africa, it is estimated that up to 90 per cent of rural and urban employment is in the informal sector.[231] In sub-Saharan Africa, it represents nearly 38 per cent of GDP; in Latin America, 40 per cent of GDP and in South Asia, 34 per cent of GDP.[232]

In many countries, the informal food sector is very large, often exceeding the size of the formal sector.[233] The informal food economy plays a crucial role in the provision of food for low-income groups in developing countries. It is also enormously important for smallholder farmers, as it is the key conduit for their production — which often includes small quantities of many different crops — to reach markets. Informal traders come to the farm, pay cash and are often willing to accept food that might be rejected by supermarkets for cosmetic reasons. Urban consumers and smallholder farmers both depend on informal food markets for their food security and livelihoods, and these markets are vital in fostering diversity in food production and consumption.[234]

Although most governments and international development organisations tend to treat informality as a vice, the informal sector is expanding in tandem with modern formal markets and continues to serve as the primary interface between small- and medium-scale farmers and low-income consumers.[235]

However, in spite of their importance, informal food markets and the vendors who sell in them are subject to many discriminatory practices and arbitrary levies which cause hardship and interfere with the proper functioning of these markets. Planners and policymakers often see the informal food sector as unhygienic, disorderly, tax-evading and detrimental to modernisation. Hence policy tends to be unfavourable to this sector and its workers. However, heavy-handed measures to regulate and police the informal sector are often ineffective.[236]

In order to address the legitimate concerns of government officials over informal markets (e.g., poor hygiene, traffic congestion, licensing, etc.), multi-stakeholder platforms which bring together all the parties involved offer a promising approach. Such platforms have already been tested in Indonesia, Uganda and other countries, with positive results (see Box 14).

FIVE STEPS FOR FOSTERING DIVERSITY ON THE FARM AND ON THE PLATE

Maintaining agricultural biodiversity is vital in order to meet food and nutrition security and to cope with the challenge of climate change.[237] Improving and diversifying diets is essential to human health and to limiting the spread of non-communicable diseases.[238] Reviving and maintaining diversity on the farm and on the plate requires action on multiple fronts and at multiple scales. At a macro level, promoting diversity entails a shift from industrial agriculture — which relies on monocultures and a small number of crops, crop varieties and animal breeds — to diversified sustainable farming systems.[239] At a national and local scale, it entails raising awareness and stimulating demand for diverse and healthy foods, as markets for diverse crops and animal products need to be supported and expanded. Meanwhile, policies, subsidies, research and extension programmes need to be aligned to support diverse food production and consumption. Finally, the cultural underpinnings of diverse food systems — which are also under threat worldwide — need to be protected and strengthened.

In a context in which citizens often have little input into food systems aside from their consumption choices, decisionmaking is frequently disconnected from the interests of both producers and consumers. How to reorient food systems towards greater diversity, health, sustainability and inclusiveness?

The first point is to realise that the two facets are intertwined: diverse agricultural production and diverse diets can be mutually reinforcing. Given that consumer demand and purchasing power shape farmers' incentives to conserve a diverse array of crops, promoting diverse diets helps to maintain agricultural biodiversity and support rural development. At the same time, diverse agricultural production can make a wide variety of foods available to consumers.[240]

Second, food systems and the policies that affect them must be made more inclusive and responsive to the needs of farmers and consumers alike. Food system issues are too complex and involve too many stakeholders for government or any single entity to address by themselves. They require multi-stakeholder approaches which can ensure that the voices of all relevant groups are heard — particularly those marginalised groups such as smallholder farmers and women who play a critical role in safeguarding agrobiodiversity.

With these points in mind, this research identifies five steps for enriching our food systems, targeted at a range of stakeholders. These are discussed in turn below, illustrated by an array of opportunities for implementing them.

Step 1: Reorient food and farming policies to encourage diversity, sustainability, and affordability

Action points

- Re-target subsidies, research and extension programmes so that they promote crop diversification rather than monocultures of a few crop varieties.
- Invest in and reorient agricultural research and extension to make a wider variety of healthy foods such as vegetables, fruits, pulses, seeds, nuts and animal proteins available to consumers at lower cost.
- Promote nutrition-sensitive agriculture approaches that put dietary diversity and nutritious foods at the centre of agricultural development strategies.
- Use taxes and regulatory instruments to ensure that the prices of ultra-processed foods reflect their true health costs to society
- Use dietary guidelines to champion diverse diets and limit consumption of ultra-processed foods (Box 9).
- Safeguard the right of farmers to save, re-use, exchange and improve their seeds by adapting laws, policies and intellectual property rights regimes (see Step 3).

Policy shifts can create an enabling environment in which positive incentives promote diversity in both consumption and production, while the obstacles and perverse incentives which are preventing this are removed. For example, policies can help to make healthy, diverse foods like fruits and vegetables more affordable, such as through greater investment in agricultural research into underutilised crops. Promoting nutrition-sensitive agriculture is another means of ensuring that agricultural development strategies prioritise diversity in food production and consumption.

Fiscal and regulatory measures are also indispensable, including taxation (e.g. Mexico's tax on sugar-sweetened beverages); restrictions on the availability of ultra-processed foods in schools; limitations on marketing and advertising; public awareness campaigns; labelling requirements; and regulations to restrict portion sizes and encourage reformulation of ultra-processed items — for instance, to reduce sugar content.[241] Trade policies have important impacts on dietary patterns, as is illustrated by the linkage between free trade agreements with the U.S. and higher soft drink consumption.[242] Planning measures — such as zoning and permits for fast food restaurants — also need to consider the need for healthy, diverse diets.

Another key is to allow informal food systems to thrive — these are often the cheapest and most accessible source of food for low-income people (Box 8). Enacting inclusive, informality-friendly policies — and revising laws and policies which are hostile to informality — are both important, as are multi-stakeholder approaches which can bring government, informal food workers and other actors together to jointly develop solutions.

Those countries which do not currently have dietary guidelines — which includes the majority of developing countries — have the opportunity to develop more ambitious guidelines from scratch (Box 9). They should emphasise the importance of eating a varied diet — particularly one rich in fruits, vegetables and whole grains — while keeping consumption of ultra-processed foods to a minimum. Any guidelines which advocate reducing consumption of sugar and ultra-processed foods will likely be met with fierce opposition from the food industry, but this pressure needs to be resisted.

Policies and programmes that empower women can have positive impacts on dietary diversity and agricultural biodiversity. As discussed earlier, there is evidence that there is a stronger relationship between these two parameters in female-headed households than in male-headed households (Box 7),[243] and that female-headed farm households plant a greater variety of crops than male-headed households.[244] Empowering women was a key factor in the success of a homestead food production programme by Helen Keller International that reached 30,000 households.[245] Furthermore, income under the control of women has been found to have significant positive effects on the dietary diversity of households.[246]

Diversifying diets and food production also involves measures outside of the food system. As the case of western Uganda illustrates (Box 2), growing a variety of crops will not lead to diverse, high-quality diets if farm households need to sell most of what they produce in order to generate cash for school fees, medical expenses and other urgent items, something that could be addressed through greater investment in education and health care.

Box 9. The role of dietary guidelines

Food-based dietary guidelines are important for raising awareness of the importance of healthy diets, while also serving as the foundation for developing food and agricultural policies. Most developed countries have official dietary guidelines, but they are lacking in many developing countries. In Africa, for instance, only five countries have developed them. Most but not all dietary guidelines emphasise dietary diversity. Only half of low-income countries with dietary guidelines explicitly recommend eating a varied diet.[247] Few guidelines specifically mention whole grains. In addition to the need to consume diverse foods, particularly more fruits, vegetables and whole grains, it is important that dietary guidelines in developing countries provide recommendations on foods which are designed to eliminate all forms of malnutrition as well as preventing diet-related noncommunicable diseases.[248]

Most dietary guidelines recommend limiting consumption of sugar and salt, although few mention ultra-processed foods specifically. Brazil is an exception. Its dietary guidelines, launched in 2014, stress the need to ensure that freshly prepared dishes and unprocessed or minimally processed foods are not replaced by ultra-processed foods, and the fact that high-quality diets should minimise these items.[249] Other countries would do well to follow Brazil's example.

The United Nations Food and Agriculture Organisation (FAO) is assisting countries, including those in Sub-Saharan Africa, in developing dietary guidelines.[250]

Step 2: Use markets to support diversity in production

Action points

- Allow informal markets to thrive to ensure an affordable and accessible source of diverse foods for low-income consumers (Box 8).
- Use procurement programmes in schools, hospitals and other public services to encourage consumption and production of diverse foods, including under-utilised crops and local crop varieties (Box 10).
- Invest in agri-food businesses that actively promote diversity, such as those that distribute local seed varieties; market under-utilised crops; bring together producers and consumers (e.g. food hubs, CSAs, farmers' markets); and that encourage healthy, diverse diets (shops, restaurants, and gastronomy movements).

For markets to foster greater diversity of production and consumption, diverse foods need to be accessible, available, affordable and acceptable.[251] In developing countries, informal markets are particularly important, and often do a better job than formal markets of linking diverse, affordable foods with consumers. Such markets should be nurtured, to support and improve their operation, rather than trying to stamp them out, as governments often unsuccessfully attempt to do (see Box 8). Barter markets can also provide an important mechanism for poor groups to access diverse nutrients and sustain agrobiodiversity. For instance, a barter market controlled by indigenous women in the Lares area of Cusco province in Peru enables highland and lowland products to be exchanged, enhancing the nutritional security and agrobiodiversity of both regions.[252]

Carefully targeted procurement programmes (e.g. in schools, university, hospital kitchens and prisons) can be another powerful lever to improve diets and create demand for a more diverse array of crops (Box 10). In fact, procurement is one of the few mechanisms that can stimulate demand and supply for more diverse, healthy foods in a direct way and at scale. School feeding programmes with the aim of improving children's nutrition are a good illustration of public procurement. Depending on how such programmes are designed, they can also promote local sourcing and a diversity of foods, thereby creating demand for local crop varieties.

In addition to promoting procurement programmes and allowing informal markets to thrive, farmers' markets, Community Supported Agriculture (CSA), food hubs and gastronomy movements (Box 11) can all be supported to help promote diverse diets and agricultural production.

Informal food market in Uganda (Sven Torfinn)

Box 10. The power of procurement

Brazil has one of the oldest and most successful school feeding programmes in the world, providing nutritious meals to over 43 million children across the country.[253] Brazil's programme has also promoted healthy eating habits in schools, while ensuring that 30 per cent of procurement is from local family farmers.[254] Brazil's example demonstrates that "local food production, school meals and nutrition education can be linked through integrated programmes and policies, improving access to healthier foods. Government leadership, strong legislation, civil society participation and intersectoral decision making are determinant".[255]

India has the largest school lunch programme in the world, serving 120 million of the country's poorest children. Many of those schools serve dishes like *khichdi*, made of rice mixed with lentils and vegetables; some schools also serve eggs, which many poor households cannot afford.[256] Biodiversity International, the M.S. Swaminathan Foundation and other organisations have promoted the conservation and use of millets, including in school lunch programmes. The substitution of millets for white rice in school lunches in 12 districts of Central and South India led to a 37 per cent increase in haemoglobin levels in children over a three-month period.[257] Millets have also been integrated into India's public distribution system since 2013, making these nutritious and under-utilised grains available to 800 million people at discounted prices.[258]

Box 11. Andean crops and the gastronomic movement in Bolivia

The Andean highlands are an important global centre of agrobiodiversity. Nutritious traditional native Andean crops such as potatoes, quinoa and cañahua have long been staples of the local populations, as well as being well adapted to the harsh climate of the region. However, many local varieties of these crops have been discarded in recent years due to intensification of agricultural production, changes in eating habits, out-migration and the decline of traditional land management and crop rotation practices. This has led to declines in on-farm crop diversity.[259]

The gastronomic movement in Bolivia has recently been promoting the revival and maintenance of traditional ingredients and flavours, including Andean cultivars. This has created a small but significant demand for traditional products by chefs, who are working directly with local producers to ensure sustainable processes for the production of these crops.

One of the key organisations involved in the Bolivian gastronomic movement is MIGA (Movement of Gastronomic and Food Integration of Bolivia). Since 2012, MIGA has brought together different key actors in the gastronomic food system to enhance the value of Bolivian culinary heritage and promote sustainable economic, social, cultural and environmental processes. MIGA seeks to promote the value of biodiversity represented in local and native products, preserving traditional knowledge, seasonality, traditional ways of consumption and promoting sustainable strategies to include them in the gastronomic environment.

Step 3. Create an enabling environment to foster local crop varieties, animal breeds and under-utilised crops

Action points

- Re-orient extension services to encourage innovation in farmer-managed seed varieties and the use of resilient and useful under-utilised crops.
- Develop markets for local crop varieties, traditional animal breeds and under-utilised crops.
- Promote combinations of scientific and local knowledge, for example through participatory plant breeding (Box 12), that bring farmers, local breeders and researchers together to develop and adapt crop varieties to local challenges and needs.
- Invest in the development of Open Source Seed Systems that allow free flow of seed varieties between farmers, local breeders and local seed companies.

Countries need to actively maintain and conserve their traditional crop varieties and animal breeds, rather than exclusively promoting modern crop varieties and exotic breeds. Local crop varieties and animal breeds should be maintained for their unique qualities, and as an insurance policy against uncertain climatic and economic circumstances, as they are often better adapted to local conditions than modern varieties and exotic breeds.

Traditional crop varieties also tend to be cheaper, more accessible, more diverse and better able to withstand climatic and other environmental stresses.[260] While their yields are often lower than modern crop varieties grown under ideal conditions, they offer economic advantages in that they can be maintained and reproduced by farmers themselves, rather than having to rely on expensive inputs. They can also be made more productive through methods such as participatory plant breeding, in which farmers and scientists work together to develop improved varieties (see Box 12).

Under-utilised crops such as millets and traditional vegetables also represent a rich resource for diversifying diets and should receive greater attention in research and extension programmes. Extension services should support these local and traditional varieties, as well as hybrids. More broadly, extension services need to work more with farmers through participatory approaches so that their services respond better to farmers' needs.

Box 12. Participatory plant breeding builds local resilience and knowledge

Participatory plant breeding (PPB), currently in use in many countries around the world, is a collaborative research process for crop improvement. PPB allows farmers and breeders to participate equally in decision making at every stage, from the identification of desirable traits and parent lines, to the evaluation of resulting varieties. PPB can help to combine local varieties — which are often more resilient — with modern high-yielding varieties to develop new varieties which are both higher yielding and more resilient. It tailors crop breeding to diverse local environments, greatly improves technology adoption rates, and generates incentives for agrobiodiversity conservation. In Guangxi province in southwest China, a maize PPB programme initiated in 2000 has increased yields by 15-30 per cent. This, along with supply to organic restaurants in provincial towns, has enhanced farmers' incomes by 30 per cent compared to non-PPB villages growing hybrid maize. It has also created incentives for the adoption of agroecological farming practices in the PPB villages (such as using ducks to control pests, intercropping and the use of manure instead of chemical fertilisers).

Sources: Song and Li (2011); Swiderska (2011)

Harvesting vegetables in Shanggula village, Guangxi province, China (Simon Lim)

Seeds are fundamental to the future of food. However, current seed laws privilege the rights of corporations, plant breeders and researchers over farmers. At a minimum, laws, policies and intellectual property rights regimes must not impede farmers' ability to save, re-use, exchange and improve their seeds. At the same time, there is an urgent need to safeguard community seed systems, which can prevent loss of local crop diversity, ensure that farmers have access to seeds, contribute to recovery from droughts and other climatic disasters and facilitate seed exchange between communities, as well as between farmers and gene banks.

Open source seed systems are designed to provide an institutional and legal framework to protect farmers' access to seed and can be an important complement to community-based seed systems.[261] Open source seed systems carry an explicit commitment to maintain the freedom to use seeds and their derivatives through any sales and exchanges. In order to promote these systems, Hivos has supported multi-stakeholder initiatives that focus on three main areas: creating viable business models for open source seed systems; using joint learning and research to nurture a budding global alliance of farmers, gardeners, breeders and consumers; and advocating for better public policies on seeds by highlighting national open source seed programmes as alternatives. These efforts have contributed to an expansion of the pool of genetic resources that farmers, gardeners and scientists have unrestricted access to.[262]

Step 4. Nurture biocultural heritage and traditional knowledge

Action points

- Focus conservation efforts on sustaining both agrobiodiversity and cultural heritage pertaining to food, as well as activities that revitalise rural livelihoods.
- Support communities to design inclusive business models, market linkages and collective governance institutions.
- Create biocultural heritage territories with clear territorial rights and boundaries as a means of protecting centres of high agricultural and food biodiversity (Box 13).

Agricultural biodiversity is the result of a long period of management by local people, so preserving the cultures that produced it and which continue to make use of agrobiodiversity is crucial for its conservation.[263] This includes the need to preserve local food cultures and culinary traditions, and spiritual values associated with particular crops, as they are an integral part of sustaining agricultural biodiversity. For instance, Mayan culinary and aesthetic preferences have been instrumental in the long-term maintenance of diverse maize varieties in

the Yucatan region of Mexico, including blue, white and yellow landraces.[264]

The concept of biocultural heritage refers to the "knowledge, innovations and practices of indigenous and local communities collectively held and inextricably linked to traditional resources and territories, local economies, biodiversity in all its forms, cultural and spiritual values, and customary laws shaped within the socio-ecological context of communities."[265] One means to preserve biocultural heritage is through the establishment of biocultural heritage territories (Box 13).

Box 13. The Potato Park, Cusco, Peru

Spanning more than 9,000 hectares and governed by six Quechua communities near Cusco, the Potato Park conserves over 650 local varieties of potato — or 1,350 according to the local classification.[266] The Potato Park has been able to diversify both production and consumption by focusing not only on food and farming systems, but also on revitalising related cultural values, beliefs, festivals and traditional knowledge of indigenous communities, as well as building collective governance institutions based on customary laws for conservation at the landscape level.

The result has been to increase food security in the face of climate change. In spite of changing climatic conditions, since 2003 the Potato Park has increased crop yields, doubled incomes and crop diversity and enhanced social capital. Cultural incentives for sustaining diversified traditional farming systems are complemented by market incentives, with growing revenues from agro-ecotourism and the sale of traditional food and non-food products (e.g. crafts, herbal teas, personal care). Tenurial incentives are provided through a collective land title.[267]

Step 5. Increase awareness and catalyse change through innovative multi-stakeholder approaches

Action points

- Use multi-stakeholder approaches such as Food Change Labs (Box 14) to create space for social innovation at the local level, allowing community members and policymakers to collaborate in the design of more sustainable, inclusive and nutritious food systems.
- Disseminate information on the need for on-farm diversity and for healthy, diverse diets through the media and educational programmes.

Food system issues such as the need to foster agricultural and dietary diversity are highly complex. The most common approaches to such problems — through simplification, analysis and trial and error — tend not to be very effective, because "they lack the capacity to match the actual complexity of the problems".[268] At the same time, it is important to recognise that many key actors — such as farmers, consumers and informal economy workers — do not participate in the governance of local food systems. What approaches do we have at our disposal to build more inclusive governance of food systems, as well as to cope with the high complexity of issues such as this, which involve many different actors, facets and disciplines? Are there effective means of reaching consensus and designing solutions that will be seen as legitimate by all parties? Innovative multi-stakeholder approaches — such as Food Change Labs[269] — can offer a way forward (Box 14).

Central to Food Changes Labs and other multi-stakeholder processes utilised by the Sustainable Diets for All programme is the notion of citizen agency — that people have the capacity to make their own choices and to act accordingly.[270] Multi-stakeholder fora offer an opportunity to bring citizen agency to the forefront of discussions and decisionmaking on food system issues.

Food Change Lab in Lusaka, Zambia (Salimu Dawood)

Educational programmes and awareness raising are also vital to create demand for healthy foods. For instance, 45 per cent of households in Kenya that had been part of a Bioversity International initiative on the nutritional benefits of African traditional leafy vegetables reported increased consumption levels of these vegetables even ten years after completing the programme.[271] Schools can also play a major role through nutrition education, school gardens, healthy meals and parent involvement.

Box 14. How Food Change Labs promote diversity

Food Change Labs,[272] a type of social innovation process, are a way of creating space for social innovation at the local level, allowing community members and policymakers to discuss and innovate in the design of more sustainable, inclusive and nutritious food systems. Together with local partners, Hivos and IIED have convened Change Labs in Indonesia, Uganda, Zambia and Bolivia.

In Indonesia, the Lab process has centred on the availability of affordable, nutritious food for low-income residents of Bandung, and particularly the role of street vendors. Working with the local NGO Laboratorium Riset Indie, the Lab has created a forum for dialogue among stakeholders who would not normally communicate with each other, namely vendors, local government, consumers, civil society and academics. Another key aspect of the Lab has been to assist communities in generating and sharing evidence which can contribute to the creation of more inclusive public policies that safeguard the interests of the urban poor.[273]

In Uganda, the Lab process has focused on the Fort Portal region (see Box 2) and builds upon years of collaborative work between the local partner Kabarole Research and Resource Centre (KRC), IIED and Hivos. Evidence gathered by KRC, IIED and Hivos under the Food Change Lab on the nexus between agriculture, economic development, growing urbanisation, and nutrition suggests that much can be gained by designing policies for inclusive and sustainable growth and the "soft" infrastructure of a food system. The Lab culminated in a People's Summit on Food held in April 2016. Hosted by Fort Portal municipality, it drew over 100 people representing local government, religious leaders, civil society organisations, food vendors, farmers, traders and school children. Each group of stakeholders voiced their commitments over live radio to build a better local food system which meets the needs of all residents.[274]

The limited diversity on Zambian farms and in local diets is the principal problem that the Zambia Food Change Lab seeks to address (Box 6).[275] Meetings have brought together more than 60 stakeholders from diverse backgrounds: farmers, youth, entrepreneurs, local and national government officials such as MPs. This Lab aims to better understand specific issues in the Zambian food system, build coalitions of stakeholders, generate ideas for change, and test these innovations on the ground. Groups involved have put forward small-scale prototypes which can help shift the food system in more sustainable directions. These include a national symposium to raise awareness of the need for agricultural diversification, establishing a radio station targeted at farmers, and an assessment of current levels of agrobiodiversity in one locality.

The process of diversifying agricultural production and diets while alleviating malnutrition is complicated and lengthy. Still, platforms like this can provide a strong impetus and inspiration while initiating new, durable coalitions for change.

CONCLUSIONS

Maintaining agricultural biodiversity is vital for food security and nutrition, and to cope with the challenge of climate change. Improving and diversifying diets is essential to human health and to curbing the growth in noncommunicable diseases. Both are key in achieving the Sustainable Development Goals (SDGs), particularly SDG2 (see Appendix 2 for details). Reviving and maintaining diversity on the farm and on the plate requires action on multiple fronts and at multiple scales, involving both women and men. At a macro level, promoting diversity entails a gradual but definitive shift from industrial agriculture — which relies on monocultures and an unsustainably small number of crops, crop varieties and animal breeds — to diversified sustainable farming systems.[276]

At a national and local scale, it entails raising awareness among consumers, policymakers and knowledge institutions and stimulating demand for diverse and healthy foods, as markets for diverse crops and animal products need to be supported and expanded. This in turn will give farmers strong incentives to practise sustainable farming methods and to conserve their traditional varieties and local animal breeds, as will reforming intellectual property rights regimes to protect the rights of farmers as well as breeders. Meanwhile, policies, subsidies, research and extension programmes need to be re-aligned to support diverse food production and consumption. Finally, the cultural underpinnings of diverse food systems — which are also under threat worldwide — need to be protected and strengthened. Inclusive governance models and multi-stakeholder approaches can help to achieve all of these ends, particularly when they use and build upon citizen's knowledge and practices to re-shape food systems.

Tushengliangping farm-to-table restaurant, Guangxi province, China (Simon Lim)

NOTES

1 http://www.fao.org/fileadmin/templates/nr/documents/CGRFA/factsheets_plant_en.pdf
2 See Wilson 2010: 287. In their 2016 report, the Royal Botanic Gardens Kew state that 5,538 plant species are currently used for human food (RBG Kew 2016: 20).
3 FAO 2016a.
4 FAO 2013a: 128.
5 Scott 1998: 266.
6 Rockström et al. 2009.
7 RBG Kew 2016: 3.
8 FAO 2015: 34.
9 Steffen et al. 2015: 736.
10 Popkin 2015.
11 On water footprints, particularly for diets higher in animal products, see Jalava et al. 2014; on carbon footprints, see González et al. 2011.
12 Hawkes, Harris and Gillespie 2017.
13 Global Panel on Agriculture and Food Systems for Nutrition 2016; HLPE 2017; Kearney 2010. While rising incomes play an important role in decreasing malnutrition, they have mixed impacts on diets. On the positive side, as national incomes increase, consumption of healthy foods such as fruit, seafood and milk tend to increase. However, consumption of vegetables and fibre tends to decline. Thus rising incomes are associated with higher intakes of both healthy and unhealthy foods (HLPE 2017: 65). There are also important differences in food consumption patterns among urban and rural populations (Hawkes, Harris and Gillespie 2017).
14 Khoury et al. 2014.
15 Khoury et al. 2014.
16 Bamji 2007; Padulosi et al. 2015.
17 Cassava is an example of a crop which is not more nutritious than staple crops such as maize which have replaced it in certain areas. Nonetheless, it is still important for food security in small-scale agriculture.
18 Wallinga 2010.
19 Popkin et al. 2012; Kearney 2010; Shetty 2002.
20 "Food systems are producing more than enough calories to feed the world today. Since 1970, the amount of food available for every person for direct consumption has increased from 2370 to 2770 kcal/person/day." TEEB 2015: viii.
21 See the World Food Programme "Zero Hunger" webpage: http://www1.wfp.org/zero-hunger.
22 See Hickel 2016 for a critique of how global hunger and poverty figures are calculated.
23 IFPRI 2016: 2.
24 IPES-Food 2017: 51
25 IPES-Food 2017: 47.
26 As the Oxford Martin Programme on the Future of Food website explains: (http://www.futureoffood.ox.ac.uk/what-food-system), "The food system, in the sense we use it here, includes all those activities involving the production, processing, transport and consumption of food. The food system includes the governance and economics of food production, its sustainability, the degree to which we waste food, and how food production affects the natural environment. We include issues of how food affects health and well-being, including nutrition, obesity and food safety."
27 https://www.iied.org/sustainable-diets-for-all
28 http://www.fao.org/fileadmin/templates/nr/documents/CGRFA/factsheets_plant_en.pdf
29 Asociación ANDES 2016.
30 Hanley et al. 2015: 124. However, Hanley et al. note that "there is considerable doubt over the precision, reliability, usefulness and interpretation of such figures."
31 FAO 1999.
32 According to the FAO (2013b:11), sustainable agriculture "conserves land, water, and plant and animal genetic resources, and is environmentally non-degrading, technically appropriate, economically viable and socially acceptable. Agricultural sustainability, therefore, is much more than ensuring protection of the natural resource base. To be sustainable, agriculture must meet the needs of present and future generations for its products and services, while ensuring profitability, environmental health, and social and economic equity. Sustainable agriculture would contribute to all four pillars of food security – availability, access, utilization and stability – in a manner that is environmentally, economically and socially responsible over time."
33 Frison et al. 2011; Bioversity International 2017.
34 Tuxill 2000: 27.
35 Le Roux et al. 2008: 44.
36 Diulgheroff and Bazile 2015.
37 IFPRI 2002: 2.
38 Vigouroux et al. 2011: 452-3.
39 Swiderska et al. 2016a: 2.
40 National Research Council 2010: 66.
41 Frison et al. 2011.
42 Hirst 2017; Mann 2006: 198.
43 Hossain et al. 2005; SATNET Asia 2015.
44 Xu et al. 2017.
45 Suh 2014.
46 Zimmerer 2010: 140.
47 Aguilar et al. 2015: 2.
48 Lin 2011: 184-187.
49 Cerutti et al. 2017: 262.

50 Wolfe 2000; Zhu et al. 2000.
51 Yoon 2000.
52 Meehan et al. 2011.
53 Mulumba et al. 2012.
54 Ebert 2014: 322; Lin 2011: 186.
55 Perfecto et al. 2004
56 Armbrecht and Gallego 2007.
57 Krätli 2015: 32-35.
58 Cook et al. 2000: 112.
59 Tuxill et al. 2010.
60 Snapp et al. 2010.
61 Chilufya 2016.
62 Ongugo et al. 2014.
63 Tuxill et al. 2010: 483.
64 FAO 2016a.
65 FAO 2011.
66 Jackson et al. 2010; Mijatovic et al. 2013; Zimmerer 2010.
67 Vigouroux et al. 2011: 455.
68 Plucknett et al. 1983: 163.
69 IPES-Food 2016: 15.
70 Tuxill 2000: 31.
71 Slow Food 2015.
72 Povoledo 2016.
73 Slow Food 2015.
74 Pollan 2009: 116.
75 Cerutti et al 2017: 256.
76 Li et al. 2014: 396.
77 Pollan 2009: 116.
78 Mathias and Mundy 2005: 62.
79 Huyen et al. 2006: 496.
80 http://foodtank.com/news/2016/09/protecting-disappearing-livestock-breeds
81 Throughout this paper I use the term 'maize', as this term is more common internationally, although it is referred to as corn in the United States.
82 Pollan 2009: 116.
83 Fausti 2015: 41.
84 Foley 2013.
85 Vigouroux 2011: 455.
86 Bezancon et al. 2009: 224; Jarvis et al. 2008: 5326; Redford and Brosius 2006: 317.
87 While the replacement of traditional crop varieties by modern varieties has taken place on a large scale since the 1960s, quantifying species and varietal loss at a global level is challenging. The figure of a 75 per cent loss in agrobiodiversity over the past century is widely referred to (e.g. FAO 2005: 3; Li et al. 2014: 395; Slow Food 2015: 1; Thrupp 1998: 23; Zimmerer 2010: 155) but is difficult to verify. Cerutti et al. (2017: 255) contend that Europe has lost 70 per cent of its agrobiodiversity since 1900, while the US has lost 93 per cent.
88 It is worth noting that not all varieties can be stored in gene banks and that gene bank collections are no longer able to evolve in response to environmental change – they are frozen, unable to reproduce and not exposed to environmental pressures. DNA analysis of 191 maize landraces in the field and in gene banks found higher genetic diversity in those that had remained in the field (Swiderska 2016b: 2).
89 RBG Kew 2016: 3.
90 FAO 2015: 34-35.
91 Scott 1998: 266.
92 FAO 2010b; FAO 2011.
93 Evenson and Gollin 2003.
94 The view that the Green Revolution helped to avert famines is widely held. For example, see Graham et al. 2007; IFPRI 2002; Khush 2001; Sasaki et al. 2002.
95 Scott 1998: 266.
96 Vigoroux et al. 2011: 453.
97 Cerutti et al. 2017: 257.
98 Scott 1998: 262.
99 Frison et al. 2011: 239.
100 IFAD 2011: 4.
101 Isaacs 2014: 103.
102 Fausti 2015: 44.
103 Mwanamwenge and Harris 2017: 15-16.
104 Bobojonov 2013: 792.
105 ETC Group 2011: 22
106 Stamp 2012: 462.
107 Harris 2013; Center for Food Safety 2013.
108 Mudzingwa 2016: 108-9.
109 Swiderska 2011.
110 Uganda Bureau of Statistics 2017: 29.
111 Sabaté et al. 2015; Shannon et al. 2015.
112 Meehan et al. 2011; NRC 2010: 66.
113 Lamichhane et al. 2017; Tabashnik et al. 2014
114 http://www.weedscience.org/
115 http://www.economist.com/blogs/feastandfamine/2014/02/bananas
116 Olson 2015; Ordonez et al. 2015.
117 http://www.fao.org/agriculture/crops/rust/stem/rust-report/stem-ug99racettksk/en/
118 ACAPS 2017; Chilufya 2016.
119 Ullstrup 1972.
120 Thrupp 2000.
121 Gurian-Sherman 2008: 64.
122 IPES-Food 2016: 15-16.
123 Roy Chowdhury et al. 2014.
124 Song et al. 2016.
125 National Research Council 2010: 66.
126 Steffen et al. 2015.
127 Tontisirin et al. 2002.

128 Helman and Greenway 2016.
129 Global Panel 2016; WHO 2015a.
130 FAO 2016b.
131 Global Panel 2016: 32.
132 Although SDG2 and its targets do not mention dietary diversity or quality specifically, they do include the need to end all forms of malnutrition and to ensure access to safe, nutritious and sufficient food for all throughout the year (see Appendix 2). As mentioned above, dietary diversity is a proxy indicator for nutritional adequacy (also see Box 4).
133 WHO 2015a.
134 Global Panel 2016: 15.
135 Ruel 2003.
136 Rah et al. 2010.
137 FAO 2010a.
138 Jones et al. 2014.
139 FAO 2013c: 5.
140 WHO 2008: 7.
141 FAO and FHI 360 2016
142 http://a4nh.cgiar.org/2014/09/12/new-dietary-diversity-indicator-for-women/
143 Ruel 2014.
144 Vorley 2018: 13-14.
145 Global Panel 2016: 56.
146 Hawkes, Harris and Gillespie 2017: 33.
147 Popkin et al. 2012: 3.
148 Drexler 2017.
149 Martínez Steele et al. 2016.
150 Pollan 2013.
151 PAHO 2015: 5.
152 Monteiro et al. 2013: 21.
153 Moss 2013.
154 PAHO 2015: 6.
155 Monteiro et al. 2013.
156 Global Panel 2016: 43-57.
157 Monteiro et al. 2013: 14.
158 Popkin et al. 2012; Kearney 2010; Shetty 2002.
159 Kearney 2010.
160 Popkin et al. 2012.
161 IPES-Food 2017: 6.
162 Imamura et al. 2015.
163 WHO 2015b.
164 IPES-Food 2017: 48.
165 WHO 2014: ix.
166 WHO 2014: xi.
167 Fanzo 2014: 187.
168 Scott-Villiers et al. 2016.
169 MISEREOR 2008: 9.
170 Global Panel 2016: 48.
171 Global Panel 2016: 74.
172 Nestle 2013: 19.
173 Tacoli et al. 2013: 18.
174 Lachat et al. 2012.
175 CAPAS 2017.
176 Global Panel 2016: 73-74
177 Of course, these macro level trends hide a great deal of diversity in rural populations – from landless poor whose access to diverse foods may be very limited, to peasant farmers and indigenous people who own their land and trade between altitudes and regions to access diverse nutrients (e.g. carbohydrates from highlands exchanged for fruits and vegetables from lowlands in Peru) – resulting in diets which are far more healthy than that of urban slum dwellers who rely heavily on fried foods. I am indebted to Krystyna Swiderska for this insight.
178 Nagaraj et al. 2013.
179 I am indebted to John Tuxill for this insight.
180 Stuckler et al. 2012: 6.
181 Malik et al. 2013; Thow and Hawkes 2009.
182 IFPRI 2002.
183 Graham et al. 2007.
184 Graham 2007; Welch and Graham 1999; Welch and Graham, 2013.
185 Bamji 2007; Padulosi et al. 2015.
186 See https://en.wikipedia.org/wiki/Millet for a comparison of nutrient levels in different kinds of millet, maize and rice.
187 Pingali 2015.
188 Zambia Ministry of Health, National Food and Nutrition Commission and Food and Nutrition Technical Assistance III Project (FANTA) 2017: 33.
189 Longvah et al. 2010; Robinson 2013.
190 Remans et al. 2011.
191 Tontisirin et al. 2002.
192 Frison et al. 2006.
193 Remans et al. 2011: 8.
194 Bioversity International 2016.
195 Bodimeade 2013.
196 Monteiro and Cannon 2012: 1.
197 Moss 2013.
198 Chandon and Wansink 2012: 575.
199 Moss 2013; Nestle 2013.
200 Gomez and Rickets 2013.
201 Reardon et al. 2003.
202 Kearney 2010.
203 Moss 2013.
204 Nestle 2013.
205 Wiggins and Keats 2015.
206 PAHO 2015.
207 Bioversity International 2016: 11.
208 Jones et al. 2014.
209 Tacoli 2015: 3.

210 Bellon et al. 2016; Frison et al. 2006; Frison et al. 2011; Herforth 2010; Pellegrini and Tasciotti 2014; Powell et al. 2015; Remans et al. 2011.
211 Malapit et al. 2015.
212 Doss 2006; Duflo and Udry 2004; Malapit 2015.
213 Wooten 2003.
214 Herforth 2010; Jones et al. 2014; Jones 2016; Kumar et al. 2015; Malapit et al. 2015; Ruel et al. 2017;
215 Jones 2016.
216 Remans et al. 2011.
217 Christink and Weltzien 2013: 693.
218 FAO 2014.
219 Talukder et al. 2010.
220 Bellon et al. 2016; Jones 2016; Sibhatu et al. 2015.
221 Dorward 2014.
222 Pellegrini and Tasciotti 2014.
223 Wooten 2003.
224 Bellon et al. 2016.
225 Keleman et al. 2013.
226 Herforth 2010: 306.
227 Tuxill 2000: 35.
228 Song et al. 2015.
229 www.hivosimpactinvestments.com/hivos-food-lifestyle-fund/
230 Weng 2015: 4.
231 ILO 2009: 6.
232 Medina et al. 2017: 13.
233 Del Pozo-Vergnes 2015; Blackmore et al. 2015; Vorley 2013
234 Vorley and Guarín forthcoming.
235 Vorley 2013: 21.
236 Blackmore et al. 2015
237 Global Alliance for the Future of Food 2016.
238 Green et al. 2016; World Cancer Fund International 2014.
239 IPES-Food 2016.
240 Diulgheroff and Bazile 2015.
241 Popkin and Hawkes 2015.
242 Stuckler et al. 2012.
243 Jones 2016.
244 Saenz and Thompson 2017.
245 Talukder et al. 2010.
246 Snapp and Fisher 2015: 94.
247 Gonzalez-Fischer and Garnett 2016: 17.
248 Global Panel 2016: 34.
249 Global Panel 2016: 37; Martinez Steele et al. 2016: 6.
250 Gonzalez Fischer and Garnet 2016: 56.
251 Bioversity International 2016: 11.
252 Marti and Pimbert 2006.
253 https://www.wfp.org/stories/brazil-champions-fight-against-hunger
254 http://www.bioversityinternational.org/initiatives/healthy-diets/
255 Sidaner et al. 2012: 989.
256 Chatterjee 2014.
257 Chatterjee 2014.
258 http://www.bioversityinternational.org/initiatives/healthy-diets/
259 Meldrum et al. 2018.
260 Swiderska 2011: 1.
261 Kloppenburg 2018.
262 See the Hivos website: https://www.hivos.org/focal-area/open-source-seed-systems
263 Redford and Brosius 2006: 318.
264 Tuxill et al 2010: 483.
265 Swiderska et al. 2009a: 4.
266 Argumedo and Swiderska 2014; Swiderska 2016b: 3.
267 Asociación ANDES 2016.
268 Del Valle 2010: 3.
269 Hassan 2014.
270 Vorley 2018: 4.
271 Gotor and Irungu 2010: 50.
272 See https://www.hivos.org/sd4all-food-change-labs and https://www.foodchangelab.org
273 Revellino 2015.
274 Vorley and Boerwinkel 2016.
275 Cook and Boerwinkel 2017.
276 IPES-Food 2016.

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APPENDIX 1: FURTHER RESOURCES

Agricultures Network produces and distributes the magazine Farming Matters as well as carrying out various programmes, projects and activities that are relevant to biodiversity.

Bioversity International promotes the protection and use of agricultural and tree biodiversity to ensure sustainable global food and nutrition security.

The Biodiversity for Food and Nutrition initiative is coordinated by Bioversity International and aims to harness agricultural biodiversity to reduce hunger and malnutrition.

Hivos' programme on Green Food and Biodiversity focuses on soil fertility, agricultural biodiversity, climate mitigation and adaptation, green knowledge development, a decent living for farmers and gender inclusiveness.

IIED's programme on biocultural heritage promotes resilient farming systems and local economies.

The Smallholder Innovation for Resilience (SIFOR) project aims to revitalise the traditional knowledge-based innovation systems of smallholder farmers to strengthen food security in the face of climate change.

Navdanya is a network of seed keepers and organic producers that operates in 18 states in India. Navdanya has helped set up 122 community seed banks across the country and trained over 5,000,000 farmers.

The Open Source Seed Initiative (OSSI) is dedicated to maintaining fair and open access to plant genetic resources worldwide in order to ensure the availability of germplasm to farmers, gardeners, breeders, and communities of this and future generations.

Southeast Asia Regional Initiatives for Community Empowerment (SEARICE) is a regional non-governmental organisation that promotes and implements community-based conservation, development and sustainable use of plant genetic resources in partnership with civil society organisations, government agencies, academic research institutions and local government units in Bhutan, Lao PDR, the Philippines, Thailand, Vietnam and Cambodia.

World map of agricultural biodiversity initiatives

APPENDIX 2: KEY GOALS AND TARGETS FROM THE SDGS

Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture.

- 2.1 By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round
- 2.2 By 2030, end all forms of malnutrition, including achieving, by 2025, the internationally agreed targets on stunting and wasting in children under 5 years of age, and address the nutritional needs of adolescent girls, pregnant and lactating women and older persons
- 2.4 By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality.
- 2.5 By 2020, maintain the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at the national, regional and international levels, and ensure access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed.

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