Introduction

Agricultural biodiversity, diverse diets and improving nutrition

Danny Hunter and Jessica Fanzo

The global malnutrition burden and addressing the challenge

One of the world's greatest challenges is to secure adequate food that is healthy, safe and of high quality for all, and to do so in an environmentally sustainable manner (Pinstrup-Andersen, 2009; Godfray et al., 2010). With the growing demand of an ever-increasing human population, it remains unclear how our current global food system will sustain itself. Compounded with climate change, ecosystems and biodiversity under stress, population growth and urbanization, social conflict and extreme poverty, there has never been a more urgent time for collective action to address food and nutrition security globally.

This burdened food system impacts the most vulnerable people, as statistics clearly show. There are currently an estimated 868 million people suffering food and nutrition insecurity (FAO, 2012). In addition to those who are hungry, there are also 171 million children under five years of age who are stunted in their growth (UNICEF, 2012) and of those children, 90 per cent live in just 36 countries (Black et al., 2008).

Malnutrition takes its toll; it is responsible for 35 per cent of all child deaths and 11 per cent of the global disease burden (Black et al., 2008). Micronutrient deficiencies, known as hidden hunger, undermine the growth and development, health and productivity of over 2 billion people (Micronutrient Initiative, 2009). At the same time, an estimated 1.4 billion adults are overweight, and 65 per cent of the world's population live in countries where overweight and obesity kills more people than underweight (WHO, 2012). This pandemic contributes to the risk of non-communicable diseases such as diabetes and heart disease. With over-nutrition, many countries and urban communities in the developing world are experiencing the nutrition transition – going from undernutrition to obesity related to insufficient exercise, sedentary lifestyles and unhealthy diets (Doak et al., 2005; Popkin, 2008).

The global community has responded to the malnutrition crisis by focusing on interventions that aim to impact 90 per cent of the global population burdened by stunting and that largely address inadequate dietary intake, disease burden and poor childcare practices (Bhutta et al., 2008). There has been a particular focus on a window of opportunity, specifically, the first 1,000 days

of a child's life from the nine months *in utero* to two years of age (Barker 2007; Golden, 2009; Victora et al., 2008). This window is critically important because nutritional setbacks during this time can result in irreversible losses to growth and cognitive development and can reduce educational attainment and earning potential (Martorell et al., 1994; Shrimpton et al., 2001; Victora et al., 2008).

These core nutrition-specific interventions are critically important in addressing nutrition insecurity, particularly during the window of opportunity. However the design, testing and scaling of more holistic multi-sectoral packages that combine child and maternal care and disease control with nutrition sensitive programming from agriculture, education, social protection, and education, have been limited in their development and implementation. Practical operational strategies for localizing and applying sensitive interventions must be further clarified and defined as to how such interventions impact nutritional outcomes. What has become clear is that agriculture is and will continue to be part of the solution in improving the health and nutrition of all populations regardless of age, during their lifespan.

Our global food system

Redirecting the global agricultural system to ensure better nutrition is important as the supplier of the world's food. The global agricultural system is *currently* producing enough food, in aggregate, but access to enough food that is affordable and nutritious for all populations has been more challenging. Most agricultural systems are extremely efficient at producing a handful of staple grain crops, mainly maize, rice and wheat. In developing countries and particularly those in nutrition transition, people obtain most of their energy from these staple grains along with processed oils and fats and sugars, resulting in diets that often lack micronutrients and other necessary dietary and health components.

Agricultural systems vary across the world, spanning large-scale monocrop landscapes to smallholdings of farmers who typically live on less than two hectares of land. Taking into account the differing agro-ecosystems and landscapes, it is necessary to understand how our agricultural system can promote positive nutrition outcomes. A recent review showed that agriculture interventions have done little to impact undernutrition (Masset and Haddad, 2012), as measured by core nutrition indicators including growth indicators. However, more research needs to be done to better understand the role of value chains, biodiversity, and ecosystem services on nutritional and dietary outcomes, and what are the best ways to measure agriculture's impact on nutrition and dietary outcomes.

Big drivers of trends in food consumption globally are the private sector, markets, processed food and diet shifts. Research and development practitioners must start thinking about new and sustainable approaches to improving the quality and variety of food produced and consumed around the world and to develop innovative new roles that agriculture can play that will ensure value chains are more nutrition sensitive, and that will improve dietary diversity and nutrition outcomes at all stages of life. To do this, nutrition must be a central goal

of agriculture and production systems, as well as value chains and marketplaces, and be recognized as a potential avenue to improving dietary diversity, quality and health as well as a means of restoring and preserving ecosystems. But one size does not fit all and this approach must ensure that agriculture – the backbone of food production – is tailored to respond adequately to the diverse conditions of major agro-ecological, socioeconomic and epidemiological situations.

Agricultural biodiversity as a potential tool for improving nutrition security

Productive terrestrial and marine ecosystems, both wild and managed, are the source of our food – a prerequisite for health and life (Millennium Ecosystem Assessment, 2008). It is well understood that the sustainability of the global ecosystem in general and of the agriculture in particular, is dependent on the conservation, enhancement and utilization of biological diversity, or biodiversity (Frison et al., 2011; Lockie and Carpenter, 2010). Biodiversity includes the variety of plants, terrestrial animals and marine and other aquatic resources (species diversity), along with the variety of genes contained in all individual organisms (genetic diversity), and the variety of habitats and biological communities (ecosystem diversity). Biodiversity is essential for humanity, providing food, fibre, fodder, fuel, and medicine in addition to other ecosystem services.

Biodiversity is the lifeblood of what we eat. Biodiversity – both wild and cultivated – underpins the sustainability of agricultural production by providing the genetic diversity and material needed to drive innovation and adaptation, as well as essential ecosystem services and processes. Far too often the human nutritional and health ecosystem services that biodiversity provides have been ignored (DeClerck et al., 2011, see Chapter 1 in this volume). When linked, biodiversity, agriculture and nutrition form a common path leading to food and nutrition security, and achievement of the Millennium Development Goals (Toledo and Burlingame, 2006).

Agricultural biodiversity (agrobiodiversity), that sub-component of biodiversity important for food and agriculture, plays an important role in productivity and the livelihoods of all farmers, regardless of resource endowment or geographical location. Agricultural biodiversity refers to the biological variety exhibited among crops, animals and other organisms used for food and agriculture, as well as the web of relationships that bind these forms of life at ecosystem, species, and genetic levels. It includes not only crops and livestock directly relevant to agriculture, but also many other organisms that have indirect effects on agriculture, such as soil fauna, weeds, pollinators, pests and predators. Agricultural biodiversity provides the basic resources farmers need to adapt to variable conditions in marginal environments and the resources required to increase productivity in more favourable settings. Agriculture is the bedrock of the food system and biodiversity is important to food and agricultural systems because it provides the variety of life (Tansey and Worsley, 1995).

FAO (2010) estimates that of a total of 300,000 plant species, 10,000 have been used for human food since the origin of agriculture. Out of these, only 150–200 species have been commercially cultivated of which only four – rice, wheat, maize and potatoes – supply 50 per cent of the world's energy needs, while 30 crops provide 90 per cent of the world's caloric intake. Intensification of agricultural systems has led to a substantial reduction in the genetic diversity of domesticated plants and animals. Some on-farm losses of genetic diversity have been partially offset by conservation in gene banks (Millennium Ecosystem Assessment, 2008). Even so, the implications of this loss of agricultural biodiversity (as well as loss of associated ecological knowledge) for the biodiversity and quality of the global food supply are scarcely understood, especially from the perspective of nutrition.

Agricultural biodiversity furthermore includes species with under-exploited potential for contributing to food security, health, income generation, and ecosystem services. Terms such as underutilized, neglected, orphan, minor, promising, niche, local and traditional are frequently used interchangeably to describe these potentially useful plant and animal species, which are not mainstream, but which have a significant local importance as well as a considerable global potential for improving food and nutrition security.

Even so the research reveals that the major causes of neglect and underuse of these important species (see Box 0.1) are often related to factors that include poor economic competitiveness with commodity cereal crops, a lack of crop improvement, poor cultivation practices, inefficiencies in processing and value addition, disorganized or non-existent market chains as well as a perception of these foods as being 'food of the poor' (Jaenicke et al., 2009).

As this book highlights, inter-species and intra-species variability represents a considerable wealth of local biodiversity and, with a better understanding of their contributions and use, could have potential for contributing to food security and nutrition. They also have considerable potential for enhancing adaptation to global climate change. Some of these species are highly nutritious and have multiple uses.

It is essential to understand how the global agricultural system and the benefits derived from agricultural biodiversity influence the drivers of global dietary consumption patterns, nutrition and health status, in particular in the developing world. The lack of diversity is shown to be a crucial issue, particularly in the developing world where diets consist mainly of starchy staples with less access to nutrient-rich sources of food such as animal proteins, fruits and vegetables. Dietary diversity is a vital element of diet quality and the consumption of a variety of foods across and within food groups and across different varieties of specific foods more or less guarantees adequate intake of essential nutrients and important non-nutrient factors. Research demonstrates that there is a strong association between dietary diversity and nutritional status, particularly micronutrient density of the diet (Arimond and Ruel, 2004; Hoddinott and Yohannes, 2002; Kennedy et al., 2007; Moursi et al., 2008; Rah et al., 2010; Ruel, 2003; Sawadogo et al., 2006; Thorne-Lyman et al., 2010; World Bank, 2006, 2007).

Box 0.1 Some barriers to the promotion and mainstreaming of agricultural biodiversity for improved diets and nutrition

- Disconnect between the biodiversity, agriculture and health sectors and other sectors (including education)
- Continued neglect by the international and national research and extension systems
- Biodiverse food-based approaches all too often fall outside the traditional scope of clinical nutrition and public health
- Lack of skills and institutional capacity necessary to promote multi-sector approaches to fully exploit biodiversity, agriculture and health linkages
- Lack of data linking biodiversity to dietary diversity and improved nutrition outcomes
- Poor information management and accessibility: relevant information is highly fragmented, scattered in various publications and reports or not easily accessible databases to policy makers and practitioners
- Lack of evidence demonstrating or comparing the most (cost-)effective methods and approaches for delivering or mobilizing biodiversity for dietary and nutrition outcomes
- Poorly developed infrastructure and markets for the majority of biodiversity for food and nutrition
- Reach and influence of the modern globalized food system and trade policies which impede or undermine promotion and consumption of biodiversity for food and nutrition and which favour the consumption of unhealthy processed foods
- Inadequate agricultural and food security policies and strategies that promote major cereal staples have often diminished the dietary role of more nutritious species such as millets, indigenous fruits and vegetables and roots and tubers
- Few practical examples on how to successfully mainstream biodiversity for nutrition objectives
- Negative perceptions and attitudes to local, nutritionally-rich traditional biodiverse foods
- Non-tariff barriers and strict food safety assessment regulations such as the European Union's Novel Foods Regulation (NFR) which places a considerable burden of proof on those attempting to bring traditional biodiverse foods and their products to markets
- The 'artificial' cheap cost of exotic or imported foods which externalize their health and environmental costs

Key research questions and potential solutions: What this book delivers

The current climate for the promotion of food-based approaches including a greater role for agricultural biodiversity to improving diets and nutrition is favourable with renewed global political interest in addressing nutrition issues through better multi-sectoral approaches. In particular, the Scaling Up Nutrition (SUN) movement (see Chapter 10) has taken up the initiative to rally political attention and action to address the problem of undernutrition through cross-sectoral action. In early 2011, IFPRI's 2020 conference on leveraging agriculture for improving nutrition and health, reiterated calls for greater synergies and partnerships among relevant sectors, and underlined the need for a new paradigm for agricultural development to be driven by nutrition goals (IFPRI, 2011; Fanzo and Pronyk, 2011).

At the global level, the Consultative Group on International Agricultural Research (CGIAR) reform process aims to develop improved research-for-development synergies with multiple actors and is prioritizing cross-sectoral collaboration. The new CGIAR Collaborative Research Programme 'Agriculture for improved nutrition and health' (CRP4) (IFPRI, 2011) is the main vehicle for achieving this and has two of four components (Value Chains for Enhanced Nutrition, and Integrated Agriculture, Nutrition and Health Programs and Policies) where agricultural biodiversity has been accorded significant recognition. This has been matched from the biodiversity community with representatives from the Convention on Biological Diversity (CBD), DIVERSITAS and IUCN calling for strengthened international cooperation for biodiversity and health (Campbell et al. 2011).

However, there remain important, yet unanswered, questions about agricultural and ecosystem biodiversity and its role in improving dietary diversity and quality, and which will help to ensure nutrition security and increased health benefits. We hope that through this book and its case studies, answers to key research questions will provide clarity for governments, development programmers, value chain and food sector actors, academic and research institutions, health and agriculture workers, farmers and communities.

Book structure

The book is divided into three parts. Part I (Chapters 1–4), describes novel and interdisciplinary approaches to nutrition, agriculture and biodiversity as well as providing an overview of agricultural biodiversity and its importance to nutrition and health. Chapter 1 makes the case for human nutrition as an ecosystem service and considers how ecology, as one element of any cross-disciplinary solution, with its focus on complex systems can make contributions to several global development challenges related to agriculture, environment and nutrition. The chapter offers refreshingly new interdisciplinary perspectives on the problem of food production, biodiversity and nutrition that offer hope for longer-term

sustainable solutions to these problems. These perspectives fall under the three 'eco' concepts of eco-system services, eco-nutrition and eco-agriculture, all of which link agriculture, human well-being, and environmental sustainability. Despite the highlighted advantages of using diversity as a development tool, it is stressed that the concepts discussed still struggle to gain wide support in the face of more targeted and short-term interventions, in part because of the focus on complexity rather than simplification. The chapter suggests that as with the management of eco-agricultural landscapes, interventions must be multifunctional and offer solutions at the expense of other development problems.

Chapter 2 provides an in-depth overview of the multiple elements of agricultural biodiversity which impact most directly on nutrition and health and how this diversity has evolved over time and been nurtured by countless generations of farmers and local communities. It draws attention to the relatively recent diminishing diversity of agriculture including loss of agricultural biodiversity and subsequent ecological, social and nutritional impacts of this. The challenge of building production systems that deliver intensification without simplification is stressed, drawing attention to the need for new paradigms such as sustainable intensification which produce more output from the same area of land while reducing negative environmental impacts including improving biodiversity. However, the difficulty of convincing governments and policy makers of the need for agricultural production practices which embody a greater use of biodiversity for food and agriculture is highlighted. Reasons for this and possible solutions are suggested including a lack of knowledge about the species that are involved; much of the evidence on their nutritional or health benefits of particular species is partial or anecdotal and there is a need for critical scientific assessments.

Chapter 3 outlines the links between changes in human food consumption patterns and animal genetic resources for food and agriculture with a focus on domesticated avian and mammalian species genetic diversity. It introduces the concept of sustainable diets largely from an environmental perspective but also touches briefly on social and economic aspects. While significant increases in food production have occurred in recent decades, largely through intensive practices, this has come with a significant cost to animal genetic resources with estimates that around one-third of cattle, pig and chicken breeds are already extinct or currently at-risk. With expected growing demand for animal food products the prospect for animal genetic resources is not promising unless major transformations occur in the food system. However we know that animal source proteins are important in improving nutrition. With the exception of marginal areas and extensive grazing systems, it is related that we can expect at the breed level that local breeds and their multiple functions and benefits will increasingly be replaced by transboundary breeds. These losses may be exacerbated by future breeding programmes which focus on narrow breeding objectives and the application of new biotechnologies may add to this. The chapter concludes by suggesting solutions which have a focus on sustainable diets which favour the conservation and sustainable utilization of animal genetic resources.

Chapter 4 deals with the role of aquatic organisms in agricultural landscapes and their importance for food and nutrition security and livelihoods of the rural poor. It argues that the integration of fisheries, aquaculture and agriculture provides numerous options for sustainable exploitation of a wide diversity of food items that can address the nutritional needs of different members of the household and society at large which are particularly important for avoiding micronutrient-related nutritional disorders. The chapter relates studies on the availability and use of aquatic biodiversity from rice-based ecosystems in Cambodia, China, Laos and Vietnam which have documented 145 species of fish, 11 species of crustaceans, 15 species of molluscs, 13 species of reptiles, 11 species of amphibians, 11 species of insects and 37 species of plants which are directly caught or collected from the rice fields and utilized by rural people during a single season. A case study from Laos is presented to illustrate this diversity which demonstrates the critical importance of flooded rice fields for the availability and utilization of aquatic organisms. While the chapter highlights that data is scarce on the nutritional composition of much of this aquatic diversity, it argues that evidence suggests it has considerable potential as a cost-effective food-based strategy to enhance micronutrient intakes or as a complementary food for undernourished children. The chapter draws attention to the fact that aquatic biodiversity is a much undervalued and neglected 'safety net' rarely captured by national statistics or reports. It stresses the need for better awareness-raising and mainstreaming to make aquatic biodiversity more 'visible' as critical. It concludes that relevant international forums and conventions – the International Rice Commission (IRC) and the Conventions on Biological Diversity (CBD) and on Wetlands (Ramsar) – recognize the importance of aquatic ecosystems and the biodiversity for food and nutrition they provide and support this aim.

Part II (Chapters 5–10) examines approaches to mobilizing agricultural biodiversity including delivery mechanisms, cross-sectoral collaborations and partnerships and markets, as well as methodological approaches and challenges to measuring biodiversity's contribution to diets. Chapter 5 discusses how homestead food production (HFP) in Mali has contributed to improved food security for nearly 150,000 vulnerable people using a cross-cutting approach to promoting agricultural biodiversity for food and nutrition with examples taken from the Millennium Villages Project. While Africa continues to struggle with significant nutrition problems the chapter points out it does have access to a high diversity of under-utilized micronutrient-dense vegetables adapted to local conditions. However these have been much neglected by research and extension resulting in reduced consumption, loss of local knowledge and genetic diversity. In this context the chapter relates how initiatives of the Millennium Villages Project enhance the role of this under-utilized diversity in improving the nutritional status and livelihoods of vulnerable groups, particularly women and children. The initiative has reported significant achievements including increasing agricultural production and enhancing ecosystem function by restoring and maintaining soil productivity, improving crop diversification, developing community gene banks, capacity building and empowerment

of women and strengthening farmer cooperatives. However, impacts on micronutrient status in target communities have yet to be published.

Chapter 6 continues the focus on Africa and examines the agro-ecology of the West Africa region and the role played by diversity within the local food systems in shaping the region's well-known but disappearing rich and healthy food culture, an often neglected topic in discussions of solving the malnutrition pandemic. The chapter reviews the changes that are taking place in the food culture and dietary habits influenced by globalization, urbanization and changes in food production practices, and the nutrition transition before outlining research and intervention programmes that have been put in place by organizations such as Bioversity International and FAO working with the West African Health Organization (WAHO), the Economic Community of West African States (ECOWAS), Réseau des organisations paysannes et des producteurs de l'Afrique de l'Ouest (Network of Farmers' and Agricultural Producers' Organizations of West Africa) (ROPPA), and national agencies and universities, to counteract these changes and which are expected to generate positive changes in the food choices of the population eventually leading to increased diversification in household diets.

Chapter 7 explores novel research methodologies employing tools used largely in ecology and agricultural sciences that might be applied to better integrate nutrition and which might help answer such questions as *how can we manage biodiversity and the ecosystem services it provides for human nutrition, while also managing other components of human well-being?* Or, *how do different plant species compositions differ in nutritional function?* Taking the latter question, and by using examples from rural villages in sub-Saharan Africa, the chapter illustrates how an ecological concept, the Functional Diversity (FD) metric, has potential to address this question by applying it to the nutritional traits of plants (and potentially animals) present in a farming system or landscape. The chapter also explores the importance of understanding possible synergies and trade-offs with other ecosystem services and components of human well-being as well as to identifying drivers of change before discussing some tools considered important for enhancing inter-disciplinary collaboration and communication among individuals and agencies working in relevant fields and sectors.

Chapter 8 focuses on three native domesticated plant species – maca, yacon and quinoa – common to South America and that have provided food to native Amerindian populations for countless generations and which have each seen in recent years quite a remarkable turnaround in terms of international profile which has contributed to considerable interest in commercial product development and research. Central to this turnaround in all three cases has been the discovery or substantiation, and growing consumer awareness, of particular nutritional attributes of each species. In particular, this chapter attempts to distil the critical factors that have shaped the re-emergence of these previously neglected crops and in doing so attempts to determine commonalities and derive broader lessons that might be important for the broader promotion and marketing of nutritionally relevant agricultural biodiversity.

Chapter 9 focuses on the role of biodiversity at the dietary level and stresses that while biodiversity has often been considered a prerequisite for dietary diversity and the health benefits that flow from having a diverse diet, the question of whether multiple varieties of single plant or animal species are required for a diverse diet is not something that is usually discussed in the biodiversity literature. Commencing with a review of what dietary diversity means and how it is measured, the chapter moves on to review the arguments made and the evidence for a relationship between biodiversity and dietary diversity. The chapter considers the magnitude of biodiversity from a nutrition perspective, and presents the case for how biodiversity and dietary diversity might be considered in nutrition programming in a rural Bolivian population. The chapter concludes by integrating information from across various sections to come up with a series of questions that should be considered prior to embarking on a biodiversity-based nutrition intervention.

Some of the chapters mentioned above have drawn attention to the multi-faceted nature of nutrition problems and provide examples of how agriculture and biodiversity can contribute to dietary diversity and quality. They have highlighted the need for improved cross-sectoral collaborations and partnerships, more effective inter-disciplinary working relations and improved integration across sectors and disciplines, all of which have parallels in renewed global calls for greater leveraging of agriculture and biodiversity for improving nutrition and health including greater synergies among the relevant sectors. The final chapter, Chapter 10, reviews how new findings from research on partnerships could contribute to more effective cross-sectoral partnerships in nutrition, agriculture and environment. The chapter explores some of the factors that have limited practical responses to previous calls for such cross-sectoral collaboration with a brief examination of pre-World War II efforts to implement multi-sectoral and collaborative approaches between agriculture and health in Malawi. This is followed by an overview of the evolution of disciplinary perspectives in the agriculture, environment and nutrition sectors which have occasionally demonstrated some meeting of concepts and approaches; yet this never seems to have been translated into practical, effective cross-sectoral and inter-disciplinary collaboration required to address current nutrition problems. The chapter concludes with an example of how a national model, Fome Zero in Brazil, has successfully linked strengthening agricultural biodiversity and improved nutrition; and an examination of what current reforms in the CGIAR and the UN Standing Committee on Nutrition might have to offer for greater mobilization of agricultural biodiversity. Finally the chapter poses the question as to what is different now that may make our future efforts more successful.

Part III comprises 12 case studies from Africa, Asia, Australia, Europe, the Pacific and South America which demonstrate practical examples where agricultural biodiversity has been deployed to enhance dietary diversity and nutrition. Case study authors were asked to provide a brief description of the context including a statement of the problem being addressed, how agricultural biodiversity was used as a solution or intervention, the mechanisms

used to mobilize agricultural biodiversity; evidence to show the impact of the intervention using targeted agricultural biodiversity; efforts to scale-up interventions using agricultural biodiversity; how the work impacted in influencing relevant policies and the key lessons learned from the work described. Highlights include the example of a community-based, Go Local, approach to promote local yellow-fleshed varieties of banana, giant swamp taro, breadfruit and pandanus rich in beta-carotene and other carotenoids to alleviate vitamin A deficiency in the Federated States of Micronesia; efforts to promote nutrient-rich small indigenous fish species in Bangladesh; the participatory tree domestication approach used by ICRAF to select and promote indigenous fruit trees with high nutritional value in sub-Saharan Africa; the role of farmers markets and community gardens as localized food systems and their potential for improving dietary diversity and nutrition, supporting biological diversity and linking production to consumption in Australia; the efforts of the Incredible Edible Todmorden (IET) initiative to address the issue of food self-sufficiency and quality of diet in the town of Todmorden in the UK; and the role of a public policy, the Food Acquisition Programme (PAA), in promoting diversification and the sustainable management of biodiversity for food and agriculture and food and nutritional security in the overall Fome Zero (Zero Hunger) strategy in Brazil.

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