Agriculture for Improved Nutrition

Seizing the Momentum

Edited by **Shenggen Fan**, **Sivan Yosef** and **Rajul Pandya-Lorch**

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IFPRI
INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

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Preface

Policy makers, practitioners and scholars working at the intersection of agriculture and nutrition are living in an unprecedented time. Never before has there been such a flurry of activity in reimagining the many ways in which our food and agricultural system can be fundamentally transformed to improve the nutrition of billions of people around the world.

In just under a decade, researchers have produced more and more literature that clearly describes the conceptual links between agriculture and nutrition, and what agricultural interventions are getting right – and what they are getting wrong – in tackling malnutrition. Practitioners have heard the call and begun improving the design of their programming, so much so that many agriculture–nutrition interventions now measure dietary diversity and women's empowerment in their day-to-day work. Policy makers are forming influential policy mechanisms at the global and regional levels, including from the United Nations, the New Partnership for Africa's Development, and multilateral and bilateral donor agencies, that call on multiple sectors, including agriculture, to combat malnutrition. Many countries are integrating nutrition into their agriculture plans, and others are laying out accountability mechanisms for the agriculture sector within their nutrition strategies. These plans reflect shifting national priorities towards nutrition and agricultural growth, and we are seeing a proliferation of tools, training programs and expert communities that together are building capacity for carrying out agriculture–nutrition work.

The knowledge gaps on the ways in which agriculture can impact nutrition are still vast. These gaps indicate that there is much more work to be done: more evidence to be generated and translated into improved programs and policies; more training and funding to build up human and institutional capacity; and more support for civil-society movements that are holding leaders and administrations accountable for reducing malnutrition. For anyone wanting to be at the forefront of groundbreaking research, programming or policy, the agriculture–nutrition nexus is the optimal place to be. We hope that this volume will inform and inspire readers to seize the momentum and help make this next decade an even more memorable one for putting agriculture to work in ending malnutrition once and for all.

Shenggen Fan
Sivan Yosef
Rajul Pandya-Lorch


A man delivers milk in Nepal. Low milk production has prompted the government to import fresh milk from India in order to meet demand. (Prashant Shrestha)

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Seizing the Momentum to Reshape Agriculture for Nutrition

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Introduction

The importance of agriculture to human welfare cannot be overstated. At its most basic level, agriculture, which includes not only plant cultivation but also animal husbandry, fisheries, and any activity occurring along the value chain from production to consumption, is the source of food and sustenance for the world's population. Ancient societies began cultivating and domesticating crops, livestock, and fish thousands of years ago. Key agricultural achievements such as irrigation, fertilizers, and selective breeding helped agriculture flourish in all parts of the globe under diverse, and at times barren, landscapes, enabling local populations to thrive. For much of history, humans have viewed agriculture as a tool of survival by way of providing enough calories.

This singular goal of agriculture, as a way of overcoming famine, carried over through the centuries and shaped the aims of perhaps the most famous achievement of modern agriculture, the Green Revolution, which focused on boosting agricultural production and productivity by investing in science and technology (to improve staple crops such as rice, wheat, and maize), irrigation, roads, and fertilizer production (Spielman and Pandya-Lorch, 2009). From 1960 to 1990, this series of investments improved access to food and/or provided a critical source of income for approximately 1 billion people (Evenson *et al*., 2006).

But for all its achievements in the areas of production and productivity, and as a source of raw materials for industry, one critical contribution of agriculture has not received sufficient attention: nutrition. Food contains more than just calories. It delivers macronutrients, such as carbohydrates, fats, and proteins, as well as micronutrients, or vitamins and minerals. Humans need these micronutrients throughout their entire life cycle, though most critically from conception to 2 years of age, in order to achieve good growth and development. The taste and quality of highly nutritious food also affects people's demand for it. Beyond food, agriculture also provides a critical source of income for the world's poorest people, enabling them to purchase a wide array of healthy foods, healthcare, and education. It is linked to nutrition through myriad other ways, including by shaping gender roles, impacting food prices, and more. Despite these intractable links between agriculture and nutrition, the global community has historically been slow to get on board in expanding its vision of what agriculture can really do.

The consequences of inaction are staggeringly high. In 2017, 821 million people were undernourished (FAO *et al*., 2018). Stunting (being too short for one's age) affected more than one in five children, or 151 million children around the world, under 5 years of age (FAO *et al*., 2018). An additional 51 million children were affected by wasting, being too thin for their height. Among women of reproductive age, 33% were affected by anemia (FAO *et al*., 2018). What is more, poor nutrition has lifelong and generations-long implications. Children who are undernourished at a young age start school later and complete fewer grade levels later in childhood (Alderman *et al*., 2006), and receive lower wages as adults (Behrman *et al*., 2004; Maluccio *et al*., 2009). Poorly nourished women give birth to poorly nourished children, perpetuating the cycle.

Agriculture feeds 7.6 billion people, and employs 69% of populations in low-income countries (FAO, 2011; ILO, 2017). It therefore has a vast potential to impact nutrition positively, a potential that has not been fully tapped. In response to this gap, individuals, organizations, and communities have begun to scale up their efforts to link agriculture and nutrition. This past decade has seen a flurry of activity to build up the evidence base on the ways in which agricultural and food systems can be redesigned and re-imagined for the benefit of nutrition.

This book seizes upon that momentum. It brings together research and programmatic advances, and policy developments at the national, regional, and global levels, during the past 5–10 years that have brought the two sectors closer together. It draws heavily from the International Food Policy Research Institute's (IFPRI) own research, as well as that of the growing agriculture–nutrition academic community, with supplementary insights from implementing and normative organizations. By highlighting the achievements – and setbacks – it offers lessons for those who want to engage in this work, whether within the policy arena, academia, or programming, and sets the stage for closing knowledge gaps and scaling up successes that can transform food systems and improve the nutrition of billions of people.

Conceptual Links Between Agriculture and Nutrition

The authors in this volume introduce a range of conceptual frameworks, reflecting their different disciplines, to describe the relationship between agriculture and nutrition. Figure 1.1 shows these various relationships, as well as the feedback loop from individual nutrition outcomes to national economic growth, and the nutrition, health, and development of populations.

As noted above, agriculture is ultimately the source of food, delivering energy, macronutrients, and micronutrients essential for growth. Diversity in agricultural production is important along with total supply: areas with higher agricultural diversity produce more nutrients (Jessica Fanzo, see Chapter 4, this volume). Also, since many food producers consume what they produce, production diversity is strongly and positively associated with dietary diversity among young children (Kumar *et al*., 2015).

Agriculture is also a source of income for farmers that they can use to purchase healthy, diverse foods, as well as services that are integral to maintaining nutrition, including healthcare and education. Conversely, this income can be also used to purchase processed, unhealthy foods that can lead to overweight, obesity, and ill health (Olivier Ecker, see Chapter 8). One instrument that can affect the linkage between agriculture and nutrition, explored in Chapter 2 by Derek Headey and William Masters, is the relative cost of nutritious foods. The authors ponder whether different sources of calories have different levels of affordability. They compare the costliness of cereals, roots/tubers, fruits, vegetables, legumes, and animal-source foods in low-income versus wealthier countries. Furthermore, they probe the extent to which high prices hinder people from consuming certain foods.

A number of pathways from agriculture to nutrition consider the role of gender, as focused on by Hazel Malapit in Chapter 6. Participation

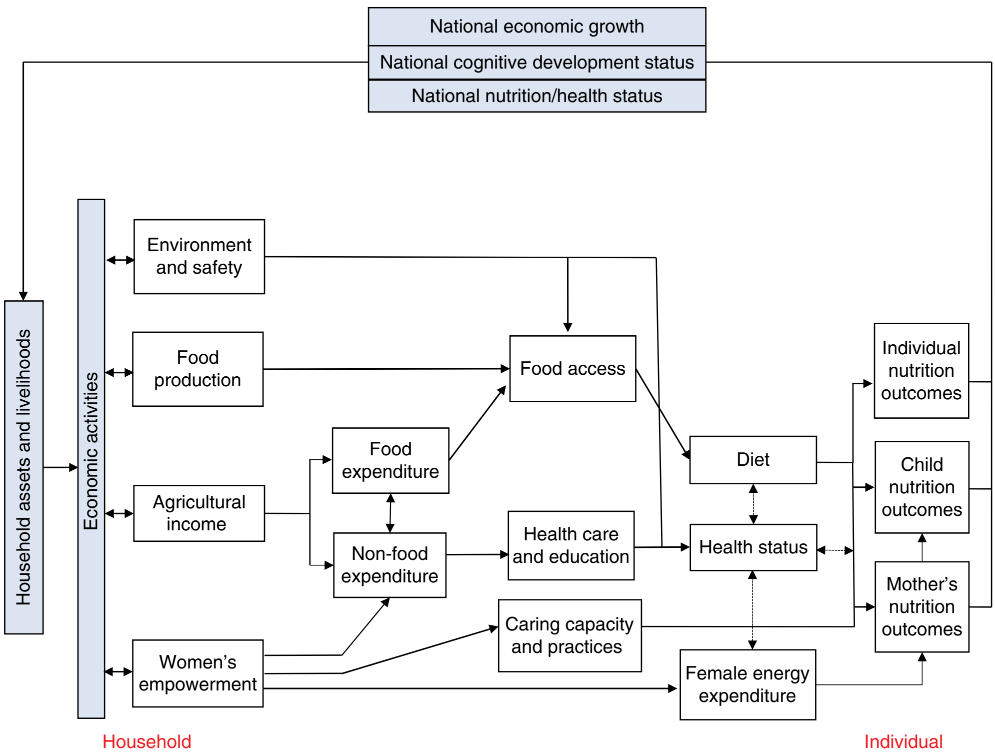

Fig. 1.1. Conceptual framework for agriculture–nutrition linkages. Adapted from Malapit (Chapter 6, this volume), Headey *et al*. (2011), Gillespie *et al*. (2012), Herforth and Harris (2014) and Kadiyala *et al*. (2014).

in agriculture may give women increased access to and decision-making power over resources, such as income, and agricultural assets such as land and livestock, which in turn can increase their social status and empowerment to allocate food, health, and care within their households (Kadiyala *et al*., 2014). Women's time, and the trade-offs they make when they participate in agriculture, such as spending time on childcare (or not), can positively or negatively affect their own nutritional status and that of their children. Exposure to occupational health hazards, and excessive energy expenditure can also impact women's health and nutrition and the transmission of undernutrition to their future children (Kadiyala *et al*., 2014). Given these links, many interventions focus on women as beneficiaries, but should the aim to empower women actually expand more broadly to achieving gender equality within households? Malapit explores the recent research and program findings on this very question.

The impact of agricultural hazards goes beyond gender to affect producers' health through zoonotic and vector-borne diseases (since agriculture also includes animal husbandry), as well as consumer health through food safety. Agricultural practices may also lead to environmental degradation and subsequently poor health and nutrition, especially as many parts of the world face additional challenges like climate change (Daniel Raiten and Gerald Combs, see Chapter 7). The agricultural system may exacerbate inequality, such as when agricultural policies favor large farms, marginalizing smallholders; or contract farming results in unequal power dynamics (Dury *et al*., 2014).

One useful way of envisaging the links between agriculture and nutrition is by using a value-chain approach, which considers how nutrition can be retained in or added to food from production and processing to marketing and consumption. In Chapter 3, Summer Allen, Mar Maestre, and Aulo Gelli explore how value chains can build up the supply of nutritious food by improving agriculture-related infrastructure and processes, such as transportation and storage; or boost demand by, for example, promoting behavior change among consumers. The authors envision great potential for scaling up nutrition-driven value chains.

A Nascent Field

Although the agriculture–nutrition relationship was probed early on by some academics, their questions mostly focused on food security or calorie intake. As such, academic and policy interest in a broad range of agriculture–nutrition linkages is fairly recent. As described above, throughout most of the 20th century, the main focus of agricultural efforts was to address food shortages by increasing production (World Bank, 2014). Up until the 1980s, most economists still focused solely on strategies to produce more energy to meet consumer demand, under the assumption that nutrition did not play a role in consumer preferences.

The nutrition community had a similarly myopic view, focusing its efforts in the 1940s–1960s on addressing protein deficiency. In the 1970s, nutritionists embraced multisectorality, advocating for the embedding of nutrition cells into larger government programs or divisions for agriculture or health within developing countries (Gillespie and Harris, 2016). This effort was largely abandoned a decade later due to lack of funding, capacity, political attention to nutrition, and poor project performance (World Bank, 2014).

In the 1990s, a small segment of the development community began to explore a wider agriculture–nutrition nexus, mainly through a focus on delivering micronutrients by consuming specific foods. In Chapter 5, Howarth Bouis, Amy Saltzman, and Ekin Birol take us through the journey of biofortification, the process of increasing the density of vitamins and minerals in a crop through plant breeding, transgenic techniques, or agronomic practices, which began in the early 1990s at CGIAR. These efforts, at the time anyway, still operated within a niche segment of the international development community. By now, nutrition professionals had shifted focus to delivering nutrition-specific interventions; agriculture professionals, on the other hand, continued on the path to improving productivity and market-led growth (World Bank, 2014). From 1973 onwards, for example, the World Bank carried out 40 agriculture projects that contained nutrition components, but nutrition was not a project development objective in any of these.

The early 2010s seemed to signal a turning point. The power of the conceptual links between agriculture and nutrition was increasingly recognized, as were the shortcomings in their real-life application. The research community released several key reviews. Masset *et al.* (2011) concluded that there was a lack of empirical evidence on nutrition status outcomes of agricultural interventions, mainly due to poor study designs. Hawkes *et al.* (2012) undertook a mapping and gap analysis of 151 research projects, one-third of which were led by CGIAR, which revealed critical research gaps on such topics as value chains, agriculture's indirect effects on nutrition, and multisectoral governance and policy processes. Turner *et al.* (2013) confirmed these results.

In 2011, IFPRI held a global policy consultation on 'Leveraging Agriculture for Improving Nutrition and Health' in New Delhi, India. The consultation gave momentum to launch the CGIAR Research Program on Agriculture for Nutrition and Health (A4NH), a large program which undertakes work on healthy food systems, biofortification, food safety, supportive policies and programs, and human health. It also prompted the Food and Agriculture Organization (FAO) of the United Nations (UN) to conduct an internal evaluation of its nutrition work, guided the UK's Department for International Development (DFID) to expand bilateral funding into the agriculture–nutrition nexus, and changed professional discourse, by 'boosting the frequency of reference to cross-sector impacts on both nutrition and health' (Paarlberg, 2012). The research underlying this conference was compiled and released by Fan and Pandya-Lorch (2012).

This book focuses on the advances in agriculture and nutrition from this critical turning point, exploring research, policy, and programmatic advances during the past 5–10 years to review what has changed, and what has not.

Recent Policy Developments

At the global level, numerous policy platforms and mechanisms have been established during the past decade to address agriculture and nutrition both directly and indirectly. The Sustainable Development Goals (SDGs), set by the United Nations General Assembly in 2015 as part of its '2030 Agenda', have an implicit focus on the intersection of agriculture and nutrition. SDG2 ('Zero Hunger'), which aims to 'end hunger, achieve food security and improved nutrition and promote sustainable agriculture', essentially combines agriculture and nutrition into one goal (Canavan *et al.*, 2016). In 2012, the UN Sustainable Development Solutions Network was formed under the auspices of the UN Secretary-General and has since been carrying out agriculture–nutrition work through its Sustainable Agriculture & Food Systems Thematic Network. The Network supports research and monitors progress toward SDG2, while also cooperating with national and local stakeholders to develop transformation pathways for SDG2.

In 2014, the International Conference on Nutrition 2 (ICN2) culminated in the release of the Rome Declaration on Nutrition, which recognized that food systems, inclusive of agriculture, need to contribute to nutritious, diverse, and balanced diets. It also noted that investing in agriculture, especially smallholders and family farmers, is essential to overcoming malnutrition. The work program of the UN Decade of Action on Nutrition, 2016–2025, provides a time-bound operational plan for achieving these aims and includes a focus on sustainable, resilient food systems for healthy diets and the support of cross-sectoral policies (WHO, 2017).

Climate and environmental change has been at the forefront of the global policy agenda for the past 5 years or so, and its links with agriculture and nutrition have been cited by some major documents and agreements. The 5th Assessment Report of the highly influential Intergovernmental Panel on Climate Change (IPCC), released in 2014, recognized the role of agriculture in contributing to malnutrition, noting an 'increased likelihood of under-nutrition resulting from diminished food production in poor regions (high confidence)'; and 'increased risks from food- and water-borne diseases (very high confidence) and vector-borne diseases (medium confidence)' (IPCC, 2014). The Paris Agreement of 2015 at the UN Climate Change Conference of Parties (COP 21) referred to food security and food production, but not agriculture. Negotiations for the 2017 UN Climate Change Conference (COP23) in Bonn, Germany, broke a deadlock on agriculture with parties agreeing to discuss issues such as soil fertility, adaptation and resilience, and livestock management, but the issue of nutrition was notably absent. However, research and development organizations remained prominent at the sidelines of COP23, holding side events on sustainable food systems and health (UNSCN *et al*., 2015). Daniel Raiten and Gerald Combs (Chapter 7) raise the question of whether we need to start using nutrition ecology as a way of understanding the complex interactions among agriculture, nutrition, and climate and environmental change on land, water, and air quality; weather; food safety; and human use patterns. Can ecological approaches, which acknowledge that food systems are affected by multiple factors, help us design locally relevant interventions that ensure both nutrition and resilience to climate change?

There has also been progress within regional policy circles, most prominently in Africa. In 2011–2013, the African Union Commission and New Partnership for Africa's Development (NEPAD) engaged 600 stakeholders from the Comprehensive Africa Agriculture Development Programme (CAADP) in a Nutrition Capacity Development Process. The process created context-specific roadmaps for 48 countries that lay out how CAADP investment plans can integrate nutrition within their objectives, targeting, implementation, communication, and evaluation. Phase II (2014 onwards, facilitated by NEPAD and FAO) focuses on improving nutrition governance at the regional level, leveraging resources for capacity building within agriculture–nutrition activities, and monitoring and evaluation (FAO, 2015).

In 2012, the G8 (Group of Eight intergovernmental political forum, 1997–2014) launched the New Alliance for Food Security and Nutrition initiative to draw the private sector into positively transforming agriculture and food production in Africa. By mid-2015, the ten participating African governments had made progress on or completed 92% of their policy commitments, which include promoting policies that 'can affect nutrition, including biofortification, fortification, nutrition policies, and malnutrition treatment' (New Alliance, 2015).

Many donors have also increased their funding for nutrition-sensitive sectors such as agriculture. During the past decade, DFID has boosted its funding of nutrition-sensitive initiatives from approximately US$300 million in 2010 to US$900 million in 2015 (Development Initiatives, 2017). During 2010–2015, agriculture, food security, and other social services represented 21% of DFID's nutrition-sensitive aid (MQSUN, 2017). The US government launched Feed the Future in 2010, which seeks to drive economic and agricultural development in low-income countries. The majority of the USA's international nutrition efforts are carried out in Feed the Future's 19 focus countries; the program received US$11 billion in 2010–2014 (Donor Tracker, 2018). USAID's Multi-Sectoral Nutrition Strategy 2014–2025 highlights the links between nutrition and supporting sectors such as agriculture (Donor Tracker, 2018). The 11 major global donors to nutrition (excluding CIFF and the World Bank, for which data was not complete) contributed US$5.45 billion to nutrition-sensitive sectors in 2015, up from US$2.97 billion in 2012; the specific allocation to agriculture was not available (Development Initiatives, 2017).

At the country level, numerous national policies have been released with the aim of bringing the agriculture and nutrition sectors closer together. Several countries have mainstreamed nutrition into their agricultural plans and strategies. Uganda's National Agriculture Policy of 2013 emphasizes food and nutrition security within its first objective, including supporting local governments in ensuring household nutrition, and promoting the production and consumption of nutritious foods, including indigenous foods (Republic of Uganda, 2013). Similarly, nutrition was incorporated for the first time into Guinea's 2011–2015 agricultural investment strategy; and Burundi's 2012–2017 National Agricultural Sector Investment Plan includes a sub-program for ensuring nutrition for vulnerable populations (SUN, 2015).

Cross-sectoral integration has been multidirectional, with some countries integrating agriculture into nutrition plans. As Kevin Chen and Zimeiyi Wang report in Chapter 19, China's National Nutrition Plan aims to produce nutritious and safe agricultural products and roll out national-level demonstration sites for researching nutritious staples and how to safeguard nutrition along the food supply chain. This is a welcome development alongside the inclusion of nutrition in the country's *No. 1 Central Document*, which has customarily focused exclusively on agricultural and rural development. But, as the authors investigate, does China's increased attention to agriculture–nutrition links carry over into programs and interventions, and whose nutrition has been left behind in the economic boom of the past three decades?

In Vietnam, the Ministry of Agriculture and Rural Development is tasked with helping carry out various components of the National Nutrition Strategy 2011–2020, including micronutrient deficiency control, nutrition surveillance, and nutrition security during emergencies (Government of Vietnam, 2012). Peru's *Incluir para Crecer* (Include to Grow) strategy, which focuses on the nutrition and development of the country's rural poor, delegates key activities to the Ministry of Agriculture; the ministry was also responsible for coordinating the National Strategy for Food and Nutrition Security (ACF, 2013).

Still other countries have focused their efforts on forming cross-sectoral mechanisms. To implement its National Food and Nutrition Policy and National Food and Nutrition Strategic Plan, the Rwandan government set up a steering committee with the Ministries of Health, Agriculture and Animal Resources, and with local government acting as co-chairs (Compact2025, 2016). Similarly, Laos established a multisectoral nutrition committee to coordinate actions and investments in nutrition; the committee is chaired by the vice minister of Health and co-chaired by the vice ministers of Agriculture and Forestry, of Education and Sport, and of Planning and Investment (SUN, 2015).

In Chapter 15, Akhter Ahmed and Julie Ghostlaw explore the agriculture–nutrition progress in Bangladesh, which has enjoyed one of the fastest prolonged declines in child undernutrition in the world, credited to households' accumulation of wealth; access to education; community-based health services; sanitation; and lastly, rapid growth in agriculture (Shahan and Jahan, 2017). In 2015, the government of Bangladesh passed the National Nutrition Policy, which, among other actions, uses multisectoral coordination to promote dietary diversity through nutrition-sensitive agriculture, including behavior change communication and food fortification (Shahan and Jahan, 2017). Ahmed and Ghostlaw ponder the role of market-induced risks for the production of crops other than rice, raising the question of how hard it actually is to diversify production into more nutrient-dense crops.

In Chapter 16, Anne Bossuyt describes how the development of Ethiopia's revised National Nutrition Program (2013–2015) closely involved the agriculture sector, which will help coordinate the program and support it by increasing the production and consumption of nutritious foods, expanding research, and integrating nutrition and gender into its own agricultural programs. The country's second National Nutrition program (2016–2020) includes strategic objectives and operational guidelines for each sector, as well as a costed action plan. Equally as consequential, the country has launched the first National Nutrition-Sensitive Agriculture Strategy, which calls on the sector to address malnutrition through production and productivity, agricultural income, and women's empowerment, and also mainstreams nutrition into various agriculture sub-strategies.

Other countries have taken innovative policy approaches to linking agriculture and nutrition. Brazil, for example, passed legislation in 2009 requiring 30% of the budget of the national school feeding program to be allocated toward purchasing food from family and local rural enterprises. Although school feeding programs are implemented in nearly all countries around the world, Brazil became the first country to legislate a link between agricultural production and school feeding (Hawkes *et al.*, 2016).

At the national level, safety nets (including conditional transfers, school meals, public works) have also proliferated during the past two decades but, as Daniel Gilligan describes in Chapter 10, social protection programs that provide complementary components in both agriculture and nutrition are scarce. Gilligan asks whether programs combining transfers with agricultural investment and behavior change communication oriented to nutrition could be effective, and determines that the right design of such an integrated program depends on policy priorities and local context.

Still, significant challenges remain. In Chapter 17, Prabhu Pingali and Mathew Abraham detail India's great strides in food security, including its passage of the National Food Security Act in 2013, which gives access to subsidized food grains for 75% of rural residents and 50% of urban residents. The Act, however, focuses on staple grains and does not attempt to address micronutrient deficiencies or protein energy malnutrition, though it does have nutritional security as an explicit aim. Pingali and Abraham point to other policies in India that show promise in better multisectoral integration, including the newly formulated (2016) National Nutrition Strategy and the draft Policy for Women, but also lament major disconnects between the two sectors. Their proposal for closing these gaps involves borrowing elements from a food-systems approach, such as looking at nutrition needs within households, not just across them, and devising ways to help especially vulnerable members.

The focus of Indian agricultural policies on grain production is similar to that of Malawi, which is characterized by policies and programs centered on maize. In Chapter 18, Noora-Lisa Aberman describes a recent shift (driven by donors, program implementers, and researchers) in pushing Malawi's agriculture sector to address malnutrition. This shift is apparent in policy statements and documents but not yet within nutrition-sensitive programming, and the author identifies some 'low-hanging fruit' or promising approaches that the agriculture sector could take to increase multisector coordination.

As countries turn their attention to malnutrition, many struggle with significant demographic shifts, such as urbanization, which (together with rising incomes) have given way to rising levels of overweight and obesity. In Chapter 8, Olivier Ecker describes how economic growth, a decades-long decline in the price of foods (such as cereals, beef, and milk), and trade liberalization have all played a part in this new nutrition challenge. Ecker explores the role of agriculture, and more specifically distortion to agricultural incentives, in the growing obesity epidemic in poor countries.

Building up the Evidence Base

For all the policy shifts around the agriculture and nutrition nexus, what does the latest evidence conclude regarding these links? Research during the past 5 years has found that the evidence base regarding the contribution of agriculture to nutrition remains weak (Marie Ruel, see Chapter 9). Numerous studies (Webb Girard *et al.*, 2012; Ruel and Alderman, 2013; Webb and Kennedy, 2014; Ruel *et al.*, 2017) have confirmed the findings of Masset *et al.* released in 2011 (described above): the majority of the evidence on agriculture–nutrition links suffers from poorly designed studies and research methodologies. These same conclusions have been drawn from regional-level reviews as well. The findings of the research consortium Leveraging Agriculture for Nutrition in South Asia (LANSA) concluded that the evidence base in South Asia was scant, especially lacking data on the role of women in agriculture and nutrition (Gillespie and van den Bold, 2017). In India, however, agriculture was found to have affected the dietary patterns of households, food prices, and incomes and expenditures. The Leveraging Agriculture for Nutrition in East Africa (LANEA) project released similar findings for East Africa: most research in the region focuses on agriculture as a source of food, and there is especially weak evidence on women's role in agriculture (Gillespie and van den Bold, 2017).

However, this conclusion belies a wealth of knowledge on the agriculture–nutrition nexus that has brought awareness and political urgency to the topic in recent years. In 2008, *The Lancet* released a series on maternal and child undernutrition, which helped lead to the founding of the Scaling Up Nutrition (SUN) Movement in 2010. In 2013, *The Lancet* released a second series on nutrition, marking the first time that nutrition-sensitive interventions (including agriculture) were analyzed. Paper 3 of the series by Ruel and Alderman (2013) focused on micro-studies showing, once again, a lack of evidence that agricultural programs affect nutrition, with the exception of vitamin A from biofortified orange sweet potatoes. However, the paper also noted that program designs have improved vastly during the past decade and are increasingly being based on strong program theory and clear impact pathways. These sound designs are charting the way for high-quality program evaluations within the next decade that could better inform agricultural and nutrition investments (Ruel and Alderman, 2013).

There have been other high-level research developments. In 2016, the EAT-Lancet Commission on Healthy Diets from Sustainable Food Systems was launched in Stockholm with the aim of achieving scientific consensus on what healthy diets entail. In early 2019, the Commission will release its final recommendations on legislative and private-sector actions that can be taken to accelerate the nutrition-sensitive transformation of the food system, with explicit recognition of the environmental, health, and nutrition challenges associated with the current agricultural system. Other key publications have included new journals (such as the *African Journal of Food, Agriculture, Nutrition, and Development*), journal special issues (*Food Security*) and seminal reports (United Nations System Standing Committee on Nutrition's *SCN News* and the FAO's 2013 *State of Food and Agriculture Report*, to name a few).

Biofortification continues to stand out as a success that is increasingly backed by solid evidence. The Copenhagen Consensus ranked biofortification as one of the highest value-for-money investments for economic development (Hoddinott *et al.*, 2012). Evaluations carried out in Uganda and Mozambique found high adoption rates among farmers, higher inclusion of vitamin A in diets of women/children, and, in Uganda, improvement of children's vitamin A status (Hotz *et al.*, 2012a, b). Additionally, an integrated agriculture (biofortified sweet potato) and nutrition intervention reduced the prevalence of vitamin A deficiency among children by 15% (Low *et al.*, 2007). In Chapter 5, Bouis, Saltzman, and Birol explore how biofortification could reach 1 billion people by the year 2030.

The chapters in this volume detail the latest research to come out on agriculture–nutrition links. In the meantime, the research community continues to move forward. Various major research initiatives have emerged through the Leverhulme Centre for Integrative Research on Agriculture and Health; IFPRI projects such as Tackling the Agriculture Nutrition Disconnect in India; the Tata-Cornell Agriculture and Nutrition Initiative; and the previously mentioned A4NH CGIAR Research Program. A number of organizations and projects, such as the International Dietary Expansion project, have improved the collection and sharing of data on agriculture and nutrition (INDDEX, 2018). Others, such as Feed the Future, are piloting ways of measuring the level of integration of agriculture–nutrition interventions (Masters *et al.*, 2014). These efforts are crucial and reflect a greater interest in data, especially big data, during the past few years. In Chapter 14, Ruthie Musker asks whether big data is just hype, or whether it truly has the power to 'disrupt' agricultural systems for the benefit of nutrition. As Musker describes the many ways in which data that is analyzed and layered together with other datasets can be used, from helping farmers prepare for weather patterns or sending decision makers early warnings about imminent famine, the answer seems to be the latter. Musker calls for greater efforts to ensure that data is responsibly collected and used, freely accessible, and easily understood by non-researchers, such as policymakers and program implementers.

Research is only one piece of the agriculture–nutrition puzzle: the research needs to be translated into actual programming on the ground. Multisectoral interventions that can diversify agricultural production, increase incomes and spending on healthy diets, water, sanitation, health and education, improve access to markets, positively change behaviors, and work toward gender equality are key in closing the agriculture–nutrition gap. During the past decade, the trend among non-profit international non-governmental organizations (NGOs) has been:

> . . . towards greater integration across sectors. Integrated programs are giving higher priority to nutrition, and new program emphases have emerged on water, sanitation and hygiene, on value chains linking agriculture to markets, and on intra-household dynamics and gender roles.
> (TANGO International, 2015)

Much of this integration has occurred within large institutions. In 2013, for example, FAO released a synthesis of guiding principles on agriculture programming for nutrition, which compiled all of the guidance, institutional strategies and other publications released by international development organizations on how to help agriculture positively impact nutrition (FAO, 2013). And, as previously mentioned, USAID's Feed the Future has been implementing agriculture–nutrition in 19 countries.

But advances are being made within smaller organizations as well. A vast majority of agriculture–nutrition interventions are now using dietary diversity scores to evaluate their impact; this was not the case in 2008 when most simply measured the consumption of specific foods. Women's dietary diversity scores are also being used, as is the Women's Empowerment in Agriculture Index, thus filling a critical gap (Herforth and Ballard, 2016). Agriculture–nutrition linkages have also begun to be integrated into many organizations' operational strategies.

A number of best practices, lessons, and tools have also emerged. The Integrating Gender and Nutrition within Agricultural Extension Services project and Global Forum for Rural Advisory Services released 'Global Good Practice Notes' on gender and nutrition in the context of agriculture extension, advising extension officers to adapt their nutrition messages to low literacy levels, make cost–benefit analyses easily understandable to smallholders, and personalize messages to local dietary patterns (Kachelriess-Matthess *et al*., 2016). FAO released its checklist and program formulation guidance note on 'Designing Nutrition-Sensitive Agriculture Investments', and Action Contre la Faim (ACF, 2018) released a series of case studies on innovative nutrition-sensitive interventions. These are just a few examples of a growing number of resources available to program designers and implementers wishing to integrate nutrition into their agricultural initiatives more effectively.

Although there are still significant evidence gaps, the role of the private sector in nutrition has also emerged as a topic of interest in recent years, as reported by Lawrence Haddad in Chapter 11. Haddad asserts that businesses have the power to improve nutrition outcomes, but whether this goal is realized depends on whether they or governments can boost demand for nutritious products through behavior change communication and price policies; whether supply of healthy foods can be boosted through innovations such as fortification, technical support, and tax incentives; and whether business practices that harm nutrition and health can be effectively regulated. Despite the fact that the big businesses can reshape entire food systems in a relatively short period of time, as evidenced by their role in the nutrition transition in many low-income countries, there are still few rigorous evaluations of the impact of private-sector engagement in nutrition – a gap that is bound to be closed in the coming years as countries continue to urbanize and markets grow (Hoddinott *et al*., 2016).

Getting the Word Out and Building Capacity at All Levels

Malnutrition is often described as an invisible issue. People living in countries with high rates of child stunting, overweight, and/or obesity often view these conditions as the norm and not requiring action. Malnutrition is also not infectious, thus further reducing its priority level for policymakers (Gillespie *et al*., 2016). Political attention to nutrition, therefore, must be built up through effective communications, advocacy, and investment in capacity. The field of nutrition has become considerably more prominent in recent years through such initiatives as the SUN movement, and the subset of agriculture–nutrition is slowly gaining visibility too.

Perhaps the largest communications feat for the agriculture–nutrition community was the announcement that the group of researchers who pioneered biofortification had won the 2016 World Food Prize (see Chapter 5 on biofortification, co-authored by one of the winners, Howarth Bouis). Two years later, HarvestPlus was selected as one of four finalists in the MacArthur Foundation's 100&Change competition, which identifies ambitious solutions for critical challenges of our time. These two achievements brought high visibility to the field. Also in 2018, Lawrence Haddad and David Nabarro won the World Food Prize for their role in elevating maternal and child undernutrition within the global and national development agendas, drawing further attention to these vital issues.

The agriculture–nutrition community has also made strides in communicating its messages to external lay audiences through a proliferation of non-technical keystone publications, such as the Global Nutrition Report (Development Initiatives, 2017) or key reports released by the independent Global Panel on Agriculture and Food Systems for Nutrition (based in London), and by the FAO's High Level Panel of Experts (HLPE) on Food Security and Nutrition; and the UNSCN. The language or 'buzz words' used to describe agriculture–nutrition links is also evolving, with the term 'nutrition-driven agriculture' being used more and more. While this shift may seem like an issue of semantics, it also represents a more forceful integration of nutrition into agricultural interventions with the message that agriculture should have nutrition as a primary, not peripheral, aim.

Other communication tools have emerged. Online communities have brought experts together for informal debates and even produced key publications, such as the Agriculture–Nutrition

(Ag2Nut) Community of Practice's release of its Guiding Principles for Improving Nutrition through Agriculture in 2013. New tools for communicating knowledge have included blogs, webinars, and even a community-led video approach from SPRING (Strengthening Partnerships, Results, and Innovations in Nutrition Globally, sponsored by USAID) and Digital Green. Major meetings, such as the Integrated Nutrition Conference hosted by Catholic Relief Services and A4NH and the annual conference of the Leverhulme Center for Integrative Research on Agriculture and Health (LCIRAH), have included the participation of not only researchers but also program implementers and policymakers. Professional gatherings are also becoming more interdisciplinary. The Milan Conference of the International Association of Agricultural Economists, for example, integrated nutritionists for the first time ever in 2015.

As Suresh Chandra Babu describes in Chapter 13, universities, donors, and governments have also joined hands to build up capacity at individual, institutional, and system levels to carry out research in agriculture–nutrition and design agricultural projects with clear impact pathways to nutrition. Various universities and organizations have integrated nutrition into curricula and are beginning to assess nutrition-sensitive agriculture competencies among their students. UNICEF India developed a nutrition curriculum for mid-level agriculture professionals, while USAID/Malawi integrated nutrition curricula into medical colleges, and agriculture and natural resources universities, modeled after similar programs in South Africa and the USA. Governments have also begun providing nutrition training to agricultural extension agents. Ethiopia's Ministry of Agriculture and Natural Resources and Ministry of Education are collaborating on integrating nutrition into mid-level agriculture curricula through the development of core competencies and standards-based courses (FANTA, 2016). Babu asks what type of capacity-building efforts will be required to scale up the agriculture–nutrition initiatives being pioneered around the world.

Academic organizations have also come on board: the IMMANA (Innovative Methods and Metrics for Agriculture and Nutrition Actions) initiative, for example, provides competitive research grants and postdoctoral fellowships for research in agriculture–nutrition, and also organizes the Agriculture, Nutrition, and Health Academy, which hosts physical and online courses and resources on relevant topics.

Research organizations such as the London School of Hygiene and Tropical Medicine (LSHTM) and implementing organizations such as CARE (based in Atlanta, Georgia) and Catholic Relief Services (CRS, in Baltimore, Maryland) have hired staff with cross-disciplinary competencies to carry out their work. The University of Michigan hired a cluster of cross-disciplinary professors to develop a food systems track, while Johns Hopkins University in Baltimore created a postdoctoral fellowship in the area of food, agriculture, and nutrition ethics.

Strengthening the Evidence and Moving to Action

The past decade has seen significant advances in linking agriculture and nutrition, within policy, research, program design and implementation. At the same time, the knowledge gaps are vast. In Chapter 9, Ruel points out that the evidence on how agriculture can positively impact nutrition is still scant. She summarizes the latest findings, which show that agricultural programs with an orientation to production diversity, biofortification, dairy, and small livestock rearing can improve production and consumption of these specific commodities. At times, these interventions may even lead to increased household, maternal, and child dietary diversity. But with a few exceptions (such as biofortified sweet potatoes), agricultural interventions are still unable to impact child stunting, underweight, or wasting. Ruel calls for more and higher-quality evidence, based on strong research methodologies, that can elucidate how to enhance the impacts of agriculture on nutrition outcomes, and furthermore, to analyze the cost-effectiveness of various integrated interventions.

The shortcomings in bringing agriculture and nutrition together are reflected not only within the evidence gaps, but also within program design. Many nutrition-sensitive agricultural interventions do not take into account that production and consumption decisions within households are often separate, and that, except for income, farming households' production decisions may not directly affect their consumption. Program designs that treat households as both consumers and producers may therefore find more success. For example, homestead food production interventions seem to be more effective in impacting nutrition when they integrate nutrition education, perhaps because they acknowledge that their beneficiaries play both roles in the food system. This approach needs to be probed further.

Indeed, topics that are critical to agriculture and nutrition have still not been explored. The contribution of value chains to nutrition, for example, especially chains centered on micronutrient-rich, perishable foods such as fruits, vegetables, dairy, and animal-source products, is a critically understudied issue (see Chapter 3). As Fanzo describes in Chapter 4, more evidence is also needed on how to manage biodiversity, comprising millions of species of plants, animals, and other kingdoms that sustain life and also support ecosystem services that are essential to agriculture, such as nutrient cycling, pest management, and pollination. Fanzo identifies critical questions, such as how can we design smart biodiversity systems that prevent biodiversity loss while also promoting nutrition, and how can value be added to nutritious crops that are at the edge of extinction, to build up demand for them once again?

As argued in Chapter 12 by Stuart Gillespie and Nicholas Nisbett, creating an enabling environment for agriculture and nutrition is perhaps the most critical action that can be undertaken to address the multiple drivers of malnutrition. These types of environment are characterized by the effective communication of knowledge, data, and evidence; political commitment; good governance; and leadership, capacity, and financing. Gillespie and Nisbett advocate that governance and leadership should not be separated: it takes leadership to implement effective systems of governance that can lead to healthier, more equitable, and more sustainable food system outcomes. They point to clear research gaps on the intersection of nutrition and political contexts, governance systems, and styles and type of leadership. Knowledge about how competing interests and trade-offs are weighed in designing integrated agriculture–nutrition policies, lessons in fostering leaders and advocates for nutrition within the agricultural sector, and how commitments can be secured to establish a stronger research and programmatic evidence base can ensure success in the future.

The agriculture–nutrition community has generated more than enough momentum during the past decade to address these knowledge gaps. Nor should these knowledge gaps be an excuse for lack of action. Policy guidance does not necessarily always need to be based on gold-standard study designs (such as randomized controlled trials, which are notoriously difficult to apply to the food system), as long as the evidence base continues to grow in incremental ways (Pinstrup-Andersen, 2013).

Indeed, it is an exciting time to be a student or professional in this field. Every day, more evidence on the agriculture–nutrition nexus is being generated. Leaders in these sectors are stepping up to advocate for nutrition and multisectorality. Capacity is being built up within people and institutions to carry out this work. These critical efforts will exponentially improve the design and implementation of interventions and policies, helping reshape the agricultural and food system, and achieve better nutrition for the world's most vulnerable people.

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A meat market in China. Rising demand for animal-source foods poses challenges for ensuring nutrition security, as well as environmental sustainability. (Andrew Hitchcock)

2

Agriculture for Nutrition: Direct and Indirect Effects

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Introduction

For most of human history, agricultural development has focused on addressing food insecurity by providing sufficient dietary energy for survival and work each day. Population growth called for increased yields of staple foods to meet daily energy requirements, particularly the cereal grains and root crops that were selected over centuries to ensure human survival and then scaled up for use in modern food systems. Rising expectations for health and longevity, as well as higher incomes, now call for more diverse food supplies, producing a wider range of plant products and animal-sourced foods that reduce disease risks and make it easier for people to pursue healthier lives. The costs of malnutrition have also made improving the ways in which food systems and agriculture function a global imperative. Undernutrition is most widespread and pronounced around pregnancy and among children less than 2 years of age (Victora *et al*., 2010), imposing lifelong costs in terms of health, cognitive function and productivity. Undernutrition also has intergenerational dimensions, affecting the children and grandchildren of its victims through each cycle of malnutrition during pregnancy and then infancy.

The scientific literature on mechanisms linking agriculture to nutrition is rapidly expanding, especially within the last decade. This chapter begins that analysis by describing three main channels through which changing agriculture can affect nutrition:

- the level and stability of real **income** and purchasing power among poor people;
- the relative **cost** and difficulty of acquiring more nutritious foods relative to other things; and
- exposure to **health** hazards associated with agricultural production, including various pathogens but also other harmful agricultural practices.

Within each channel, we highlight recent research findings that have strong implications for the way in which agriculture can be redesigned to improve nutrition.

A Simplified Conceptual Framework for Agriculture's Effects on Nutrition

Later chapters of this book and many previous studies have sought to conceptualize the complex relationship between agriculture and nutrition (Hoddinott, 2011; Headey *et al*., 2012). Here we focus on the three basic linkages that encompass a number of specific interconnections, as illustrated in Table 2.1.

A first lever for agriculture to improve nutrition is through household income and productivity. In low-income countries there are far more workers than there are non-farm jobs, and many of the poorest people have no choice but to do at least some farming to meet daily needs. It is the children of these farm families who are at greatest risk of undernutrition, as their household's total income determines whether they can afford to use a wide range of nutritionally relevant goods and services, including food, health care and education as well as water, sanitation, and hygiene (WASH). Public investment targeting staple foods remains key to raising poor people's real income, purchasing power, and time availability, by freeing their labor and resources for other things.

A second linkage between agriculture and nutrition is through the relative cost of more nutritious foods. After households meet daily energy needs, increasing access and reducing prices for nutrient-dense and healthier foods helps people improve their diet quality. In coastal cities that trade freely with the rest of the world, easily shipped food commodities can originate anywhere, so prices are set by demand and supply among all trading partners. In the poorest rural areas, local agriculture plays a larger role, until market infrastructure and institutions are able to provide similar access to lower-cost, higher-quality foods around the year. Spatial and seasonal variation in prices tends to be greatest in the places where malnutrition is most widespread, especially for perishable products such as eggs, fresh dairy produce, and many fruits and vegetables. For these items, transport and storage costs are so high that prices even in coastal cities will be determined by national agricultural systems (Headey *et al*., 2017a). In these situations, farm output depends on local demand, so agriculture–nutrition linkages work

Table 2.1. Conceptualizing basic and specific linkages between agriculture and nutrition.

Basic linkages	Specific linkages	Comments
Income and resources per person	(a) Farm profits increase household incomes	Majority of the poor still work in agriculture
	(b) Off-farm income (off-farm and non-farm wage incomes and profits) contribute to household incomes	Substantial numbers of poor people work in off-farm or non-farm occupations
Relative **costs** of more nutritious foods	(a) Changes in production affect relative prices of different foods	Many nutritious foods, such as dairy produce, are imperfectly tradable, implying prices are heavily influenced by local supply and demand
	(b) Changes in trade policies affect relative prices of different foods	Many food sectors are still highly protected
	(c) Changes in transport and storage affect relative prices of different foods	Many foods are highly perishable and not traded long distances
Livelihood effects on **health**	(a) Farming practices affect time use of parents and children	Women's time use may be associated with less care towards young children
	(b) Farming practices can directly affect health through diseases, exposure to chemicals, and level of physical activity	Zoonotic diseases, including enteric and pulmonary infections Exposure to pesticides, herbicides Physically arduous tasks during pregnancy
	(c) Agricultural livelihoods affect empowerment of women and children	Women's control of agricultural assets is highly variable
	(d) Agricultural livelihoods influence access to nutrition-relevant goods and services	Remoteness and low population density reduce access to health, education, family planning and WASH[a] services

[a]WASH: water, sanitation, and hygiene

through prices as well as income. For example, fresh milk is highly perishable and expensive to transport, so farm families with a lactating cow have much lower-cost access to milk each day and are more likely than others to feed milk to their children (Hoddinott *et al.*, 2015). More generally, the imperfect tradability of many fresh foods means that we should expect to see strong associations between local production patterns and local consumption patterns, and even between household production and household consumption.

A third basic linkage involves the broader non-market dimensions of agricultural livelihoods. These encompass the effect of farming practices on time use and exposure to health hazards, cultural norms and institutions such as women's control over assets, and access to nutrition-relevant goods and services. Some modern agricultural practices may be beneficial to health and nutrition (e.g. more modernized livestock management, labor-saving technologies, improved storage facilities), and some may not be, especially if improperly used (e.g. pesticide use). Examples are provided below.

Agricultural Growth as a Driver of Incomes

A substantial body of literature explores linkages from agricultural growth to the total amount of available resources for improved nutrition (Bershteyn *et al.*, 2014; Masters *et al.*, 2018). Agricultural growth can impact nutrition directly through households' own income or wealth, and indirectly through government investments in such areas as rural market infrastructure, rural education (especially for girls), and sanitation, as well as service provision, particularly for maternal and child health.

Figure 2.1 uses data from the multi-country Demographic and Health Surveys (DHS), pioneered by the US Agency for International Development (USAID), to illustrate the linkages between agricultural income and nutrition outcomes by examining stunting prevalence in sub-Saharan Africa and South Asia. The data are disaggregated by locality (rural/urban), father's primary occupation (farmers, manual workers, services, professional), household wealth (the average number of six assets owned), and the number of people in each occupational category. Several striking findings are noticeable in Fig. 2.1.

1. In Africa the largest share of children live in households where the father primarily relies on farming for a living, while the rural and urban manual and services occupation clusters all have broadly similar population sizes. In Asia, more children live in rural non-farm households (manual plus services), and more of the population is urbanized.

2. There are very strong associations between locality–occupation categories and household wealth. In Africa, the poorest rely on farming and all rural households are substantially poorer than urban households. In South Asia, where landlessness is more common, the wealth differences between farm and non-farm occupation is not marked, and rural–urban differences in wealth are evident but not as pronounced as they are in Africa.

3. In Africa, children of farming households have by far the highest rate of undernutrition, with almost 50% stunted in the 24–59-month age range. Stunting rates are lower in rural non-farm occupations and substantially lower for more urbanized livelihoods. The association between stunting and wealth is much more pronounced in Africa than in Asia, where stunting is still high in urban services and urban professional households.

Overall these findings suggest that agriculture growth is likely to have more impact on stunting in Africa than in Asia, because stunting there is more closely associated with poverty, with farming as a livelihood, and with rural living in general. In the more structurally advanced economies of South Asia, the income role of agricultural growth is somewhat more limited.

Agricultural Change and Food Prices

Food affordability has long been viewed as an important linkage between agricultural productivity, poverty, and food security. Most analyses compare food prices with non-food prices, wages or incomes. Many analyses also focus on the price of staple foods. Given the importance of protein-rich and micronutrient-rich non-staple foods for nutrition, however, a more important question is how affordable these non-staple foods are relative to staples. In other words, how costly is it to diversify away from staples?

A recent study by Headey *et al.* (2017a) addressed the affordability of different sources of calories in 177 countries. They used national price data for 200 specific standardized food products and converted the prices of all foods into a price per calorie. They then took the ratio of each food's caloric price to the price of the cheapest staple cereal in each country (since cereals are consumed everywhere and are highly tradable). These 'calorie price ratios' revealed the costliness of diversifying away from the cheapest staple in any given country. Their results showed that prices of different foods were highly variable across countries and across different income levels, particularly for less tradable products such as eggs, fresh milk, and some (but not all) fresh fruits and vegetables. Figures 2.2 and 2.3 show scatter plots of these calorie price ratios for seven food groups and for fortified infant cereals (which are a potential alternative means of diversifying the diet with a complete range of essential nutrients) against the gross domestic product (GDP) per capita of a sample of countries. In this large sample of countries, per capita income varies from just US$617 per capita in the Democratic Republic of Congo to approximately US$50,000 per capita in the USA. The results reveal important findings.

1. The prices of roots/tubers, vitamin A-rich fruits and vegetables, and other fruit/vegetables have no significant relationships with per capita income, and these foods are often relatively cheap sources of calories. Root/tuber calories are often as inexpensive as cereal calories, if not cheaper, and in many countries the cheapest fruits and vegetables are only 2–5 times as expensive as cereals (bananas being a particularly cheap source of fruit-based calories).

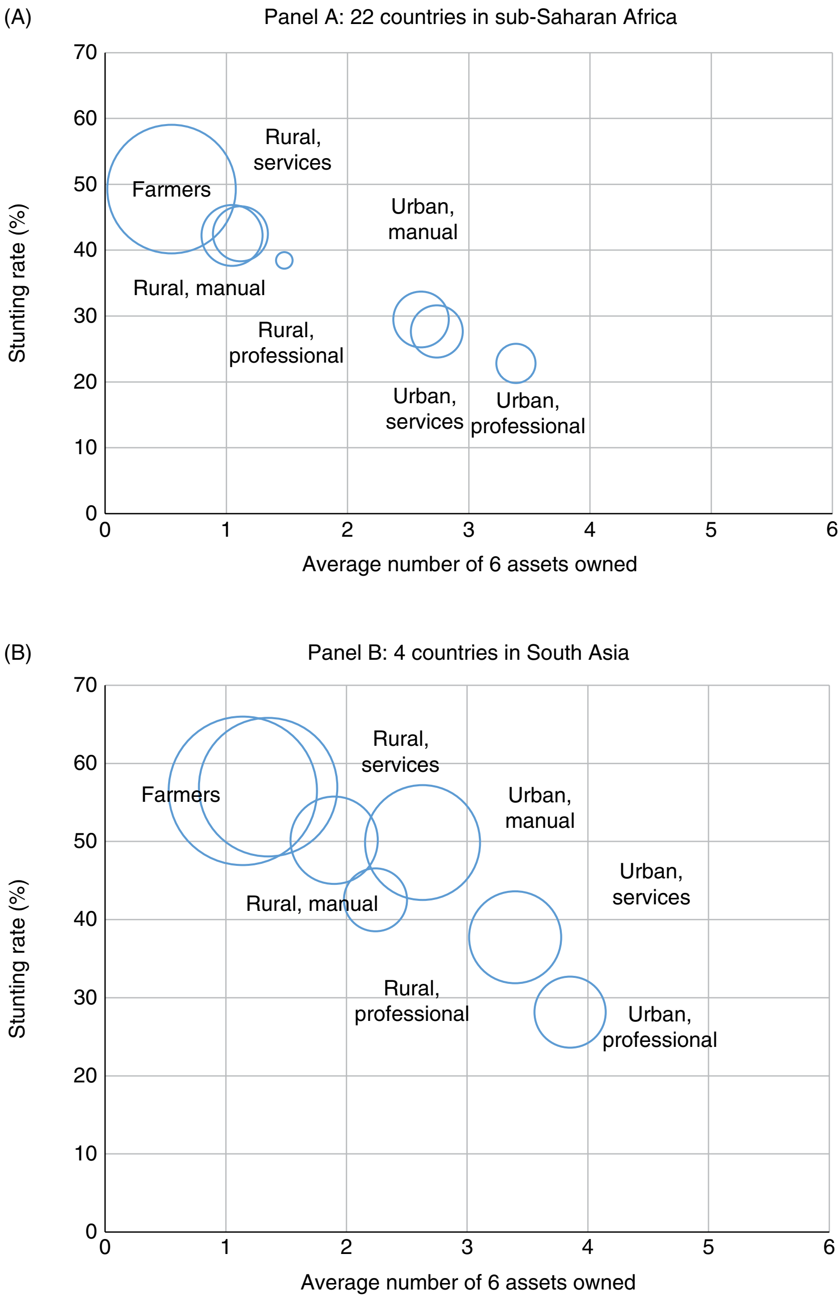

Fig. 2.1. Stunting rates for children aged 24–59 months, by location, father's occupation, and assets owned: (A) 22 countries in sub-Saharan Africa; (B) four countries in South Asia. Data are estimated from the Demographic and Health Surveys (DHS). Rural/urban classifications follow the DHS (national) definitions, except that all farming households are classified as rural. Circle sizes reflect the size of the sample of children in each locality–occupation class. Ideally this measure should use sample weights, since the DHS over-samples urban areas, but since many surveys are several years old we do not apply weights, in order to allow for recent urbanization trends. The six assets in question are a TV, motorbike, car, refrigerator, electrification, and an improved floor material. The four countries in South Asia are India, Pakistan, Bangladesh and Nepal.

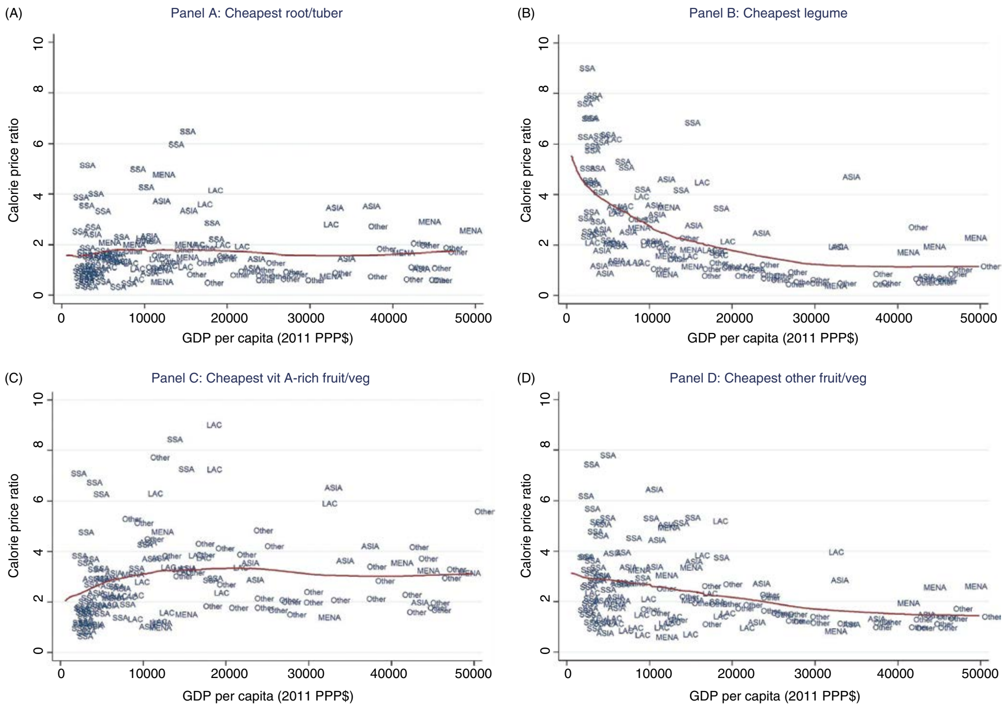

Fig. 2.2. Calorie price ratios (relative to the cheapest cereal) for various vegetal-based foods: (A) cheapest root/tuber; (B) cheapest legume; (C) cheapest vitamin A-rich fruit/vegetable; (D) cheapest other fruit/vegetable. Data are extracted from Headey *et al*. (2017b). Red lines show LOWESS curves to allow for non-linear functional forms. Individual observations are marked by the following regional groupings: sub-Saharan Africa (SSA); Latin America and Caribbean (LAC); South Asia and East Asia (ASIA); Middle East and North Africa (MENA); all other countries in Europe, North America, and Australasia (Other).

2. Higher prices of protein-rich legumes, animal-sourced foods and fortified infant cereals have strong negative associations with per capita income, though there is a large price variation at low income levels. For example, in the poorest countries legumes are 4 times as expensive as the cheapest cereal on average, but in some poor countries legumes are equally cheap as cereals and in others they are 7–8 times as expensive. Amongst milk products, both fresh milk and powdered milk are included, but only the latter is highly tradable. Despite this, milk prices vary markedly even within low-income countries and milk is often 4–6 times more expensive than the cheapest cereal. Flesh foods (meat, fish) show a similar relationship, but eggs are a far more expensive source of calories in low-income countries where they vary between being 4 to 15 times as expensive as cereals. Eggs are an extreme case of a food product that is difficult to trade long distances (especially in countries with underdeveloped value chains), so the prices of eggs are largely determined by productivity levels in the domestic poultry sector, which is generally low in poorer countries. In contrast to eggs, fortified infant cereals are highly tradable products, but still extremely expensive in lower-income countries, often 10–30 times as expensive as conventional unfortified cereals. This potentially surprising result likely stems from a basic information asymmetry problem: parents have little trust in locally produced infant cereals, and instead opt for very expensive multinational brands if they can afford them (Masters *et al.*, 2017).

The results above suggest that the relative price of nutrient-rich foods, particularly protein- and micronutrient-rich animal-sourced foods, is very high in low-income countries, but declines as a country becomes wealthier. Moreover, Headey *et al.* (2017b) showed that the high prices

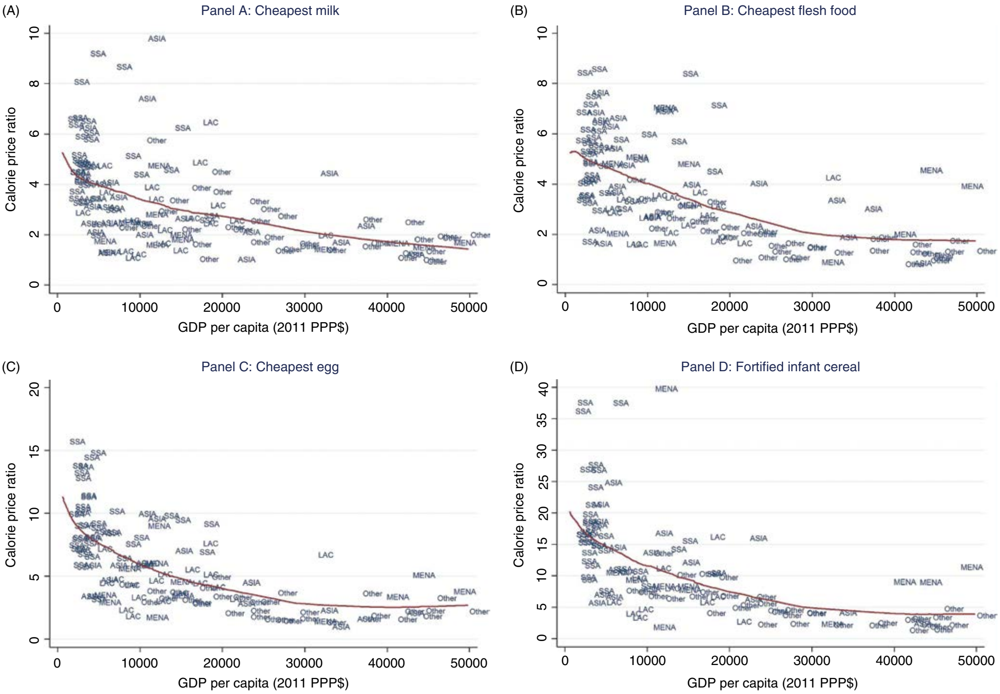

Fig. 2.3. Calorie price ratios (relative to the cheapest cereal) for various animal-sourced foods and fortified infant cereals: (A) cheapest milk; (B) cheapest flesh food; (C) cheapest egg; (D) fortified infant cereal. Data are extracted from Headey *et al*. (2017b). Red lines show LOWESS curves to allow for non-linear functional forms. Individual observations are marked by the following regional groupings: sub-Saharan Africa (SSA); Latin America and Caribbean (LAC); South Asia and East Asia (ASIA); Middle East and North Africa (MENA); all other countries in Europe, North America, and Australasia (Other).

of animal-sourced foods (ASFs) significantly explained the low consumption of ASFs in lower-income countries, as well as specific ASF consumption patterns with lower-income regions. For example, fresh milk and eggs are extremely expensive in sub-Saharan Africa, and their consumption is low, whereas fish is relatively cheap in most of Africa and its consumption is high. The high prices of ASFs, as well as some vegetal foods, clearly provides an opportunity for policies to greatly improve the affordability of these foods, as discussed in the concluding section.

This section has described cross-country variation in prices, but there is also an extensive literature on variation in opportunity costs or 'shadow' prices within countries. Shadow prices are the value of labor or other things needed to acquire each food even when explicit prices do not exist because of missing or incomplete markets. Markets might fail to provide an adequate supply of all foods because of the perishability of certain foods – particularly eggs, fresh milk and many fruits and vegetables – and because local demand for these products is quite limited in low-income and low-density rural populations. Faced with imperfect supply from markets, households make production decisions that are designed to satisfy their consumption demands. For example, in Ethiopia over 90% of the milk produced by a rural household is consumed by that household (Hoddinott *et al*., 2015). In this situation there are, unsurprisingly, strong associations between cattle ownership and children's milk consumption, but also between cattle ownership and child growth outcomes. Many other studies have linked livestock ownership to increased consumption of ASFs (Kabunga *et al*., 2017), and local crop diversity to dietary diversity (Dillon *et al*., 2015; Jones, 2017). Overall, these results strongly suggest that there are high degrees of market failure in developing countries, leading to a high degree of dependence on local agricultural systems and vulnerability to local shocks.

Agriculture, Rural Livelihoods and Nutrition

As shown above in Fig. 2.1, stunting rates and absolute numbers of stunted children are significantly higher in rural areas of sub-Saharan Africa than in urban areas. Figure 2.1 also provides at least one explanation of this phenomenon: rural people are simply poorer than urban people, as measured by household assets. However, wealth differences provide only one likely explanation of the nutritional disadvantages of rural populations, since there are many other dimensions of rural living that might also contribute to undernutrition. Earlier research concluded that this rural–urban inequality in nutritional status stemmed from differences in 'endowments' – such as wealth, education and access to services – rather than from the nutritional returns to these endowments (Smith *et al.*, 2004). Headey *et al.* (2017d) extended this research for a broader range of sub-Saharan African countries to examine both rural–urban differences, and differences across different degrees of remoteness (as measured by proximity to small cities). Strikingly, the results implied that proximity to cities is not important independent of its associations with wealth, education and access to services. Instead, remote villages – and rural villages in general – are simply characterized by poverty, low levels of human capital, and poor access to services. Indeed, these authors extended the rural–urban decompositions of earlier work to find that differences in endowments such as wealth, education, and access to services explained 77% of the observed difference in stunting rates across rural and urban areas. Differences in socio-economic status (wealth and non-farm employment) accounted for almost 40% of this difference, followed by parental education (19%) and health/infrastructural services (11%). They found similar results for rural–urban differences in child dietary diversity. An implication of these results is that physical remoteness seems to primarily influence nutrition through its harmful impacts on multidimensional poverty, including vulnerability to shocks (Mulmi *et al.*, 2016).

Beyond problems with remoteness and poor access to services, most rural populations still primarily work in agriculture, which presents its own potential health and nutritional hazards. A mostly qualitative literature, particularly in South Asia, has explored associations between women's employment in agriculture and maternal nutrition, including substantial workloads during and soon after pregnancy (see Headey *et al.* (2012) for a review of earlier studies on this subject). One important concern is that physical exertion – especially in conditions of high temperatures – may be harmful for women's nutrition, including weight loss. This literature also expresses concerns about the impacts of women's workloads on their ability to care for children, including breastfeeding and dietary diversity. Headey *et al.* (2012) examined whether agricultural mothers in India were more likely to leave younger children in the care of others. They found that while this practice was common for agricultural women, it was also common for women in other unskilled occupations. Overall, though, there is little solid empirical evidence on whether agricultural employment is harmful to maternal or child nutrition beyond the obvious associations between employment in agriculture and general socio-economic poverty.

Other research has examined specific biological mechanisms linking agricultural livelihoods to health. For example, Brainerd and Menon (2014) looked at the longstanding concern that excessive and inappropriate use of chemical inputs, particularly pesticides and herbicides, has harmful effects on health and nutrition. They found significant evidence of adverse impacts on maternal and child health, including birthweight. More recently, Sheahan *et al.* (2017) examined pesticide use in five sub-Saharan African countries and found that pesticide use was associated with greater health expenditures and more sick days, though they did not test associations with child nutrition outcomes.

Another strand of research has looked at health problems associated with livestock ownership. Formative research in a rural Zimbabwean village monitored children for 12-hour periods (Ngure *et al.*, 2013). The study found that a large proportion of children directly consumed chicken feces, and dirt that may have been contaminated with chicken feces. They also showed that the bacterial loads of chicken feces were some 10,000 times higher than dirt and other surfaces in the household. They argued that ingestion of such high loads of bacteria might contribute to environmental enteropathy, a chronic but latent infection of the gut that has been strongly linked to child stunting. Subsequent research in Ethiopia (Headey and Hirvonen, 2016) and Bangladesh (George *et al*., 2015) found that children living under the same roof as poultry were more likely to be stunted, and a three-country study by Headey *et al*. (2017c) found that homesteads in Bangladesh and Ethiopia with observable animal feces in the compound had shorter children. A systematic review of diarrheal studies also found significant associations with livestock ownership in a majority of studies (Zambrano *et al*., 2014). Hence, despite the importance of animal-sourced food intake for child nutrition, and the clear associations between livestock ownership and ASF consumption, there are also negative pathways between livestock ownership and child growth. These pathways presumably operate mainly through fecal contamination and enteric infections, though pulmonary infections associated with poultry ownership are a potential concern (Gomaa *et al*., 2015), as is the connection between cattle ownership and malaria (Donnelly *et al*., 2015).

Conclusions

Historical and comparative evidence discussed in this chapter suggests that agriculture's impact on nutrition can be seen to operate through three main levers, with a wide variety of other dimensions explored in later chapters of this book.

A first lever for agricultural change to improve nutrition is via real incomes and poverty reduction. Agricultural growth – including growth in staple food production – has been shown to be a historically important driver of poverty reduction because so many poor people directly and indirectly depend on agriculture for a living (Diao *et al*., 2010). Evidence reported above suggests that agricultural growth is still likely to be an important driver of poverty reduction in South Asia and especially in sub-Saharan Africa, in ways that are heavily influenced by the local context (Dercon and Gollin, 2014).

The second lever explored in this chapter is through altering the relative price of nutritious foods. Headey *et al*. (2017a) showed that critically important animal-sourced foods are a very expensive source of calories in sub-Saharan Africa and much of Asia. Moreover, higher prices of ASFs are strongly and negatively associated with children's consumption of ASFs, suggesting high prices are a major constraint to ASF consumption, and perhaps to other nutrient-rich foods. Micro-econometric evidence also sheds light on the importance of incomplete markets; there are strong associations between agricultural assets/agroecological characteristics and consumption patterns, including consumption among infants. This suggests that in many localities certain nutrient-rich foods are either not affordable or not accessible in the market, forcing farmers into potentially inefficient self-reliance. The costliness of highly nutritious foods in lower income countries perhaps provides the strongest mandate for nutrition-focused agricultural development; other economic sectors may well drive income growth, but only food policies can influence the affordability of nutritious foods. These roadblocks highlight an opportunity for policy to improve the affordability of nutritious foods by, for example, setting quality standards for locally produced food products or improving market and transportation infrastructure in order to enable access to highly perishable, healthy foods.

A third agricultural lever for nutrition is through the transformation of agricultural livelihoods. These livelihoods consist of farming as an occupation, but also rural living, and all that it entails for maternal nutrition and empowerment, child care practices, and access to nutritionally relevant goods, services and infrastructure. In developing countries rural populations pervasively have nutrition outcomes that are significantly worse than urban populations, and there is no mystery as to why this is so: rural populations are much poorer and have substantially less access to essential goods and services. Yet they also face specific hazards associated with agricultural living, including exposure to potentially harmful chemical inputs, physically arduous work (including mothers), and highly unhygienic environments due to excessively close proximity to livestock. Continued research on the impact of these hazards on nutrition and health can help policies and programs minimize them in the future.

There are many opportunities for productive research to guide policy choices regarding how agriculture affects nutrition. In recent years our understanding of agriculture–nutrition linkages has vastly improved, but many knowledge and policy gaps remain. Much more emphasis is needed on how policies influence diets through income and price changes, what tradeoffs may exist between poverty and nutrition targets, and on how multisectoral rural development efforts can improve access to basic services and reduce farming's hidden health risks.

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Workers package asparagus in Peru. The country is the largest exporter of fresh asparagus in the world. (UNIDO)

3

Food Value Chains for Nutrition

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Introduction

Despite the UNDP's second Sustainable Development Goal of ending hunger and preventing malnutrition in all its forms by 2030 (see Chapter 1), the world actually saw an increase of chronically undernourished people in 2016, from 777 million to 815 million (FAO *et al*., 2017). Stunting affected 154.8 million and overweight affected 40.6 million children under 5 years of age in 2016 (UNICEF *et al*., 2017).

There continues to be a number of challenges in addressing malnutrition. These include a lack of access to nutritious foods, whether due to lack of infrastructure and markets in rural areas, or limited availability or resources to purchase more nutrients foods in both urban and rural areas. Climate change can also impact nutrition and health by contributing to yield losses or post-harvest exposure to pathogens, such as aflatoxins, due to lack of appropriate storage or transportation infrastructure. Food access can be further hindered by an unsupportive enabling environment that does not foster nutrition-targeted policies or incentives for businesses to improve nutrition.

One mechanism for bridging the food access gap is through the use of agricultural value chains that support the production and consumption of nutritious foods (Gelli *et al*., 2015; Allen and de Brauw, 2018; Ruel *et al*., 2017). By definition, value chains include all of the actors and processes involved in manufacturing a product (including conception and delivery to final consumers as well as disposal after use). Analysis of value chains considers where value is added to the product or actors along the chain, the roles and the interactions amongst them and the power they hold (Hawkes and Ruel, 2011). Inclusive value chains for nutrition take into account these interactions and determine entry points for interventions targeting the supply and demand of nutritious foods, as well as strategies and policies that can increase nutrition, increase the incomes of smallholders involved in different chains, reduce loss and waste or create a better enabling environment for nutrition (FAO, 2016).

Most comprehensive discussions of nutrition center on overall diets; value chain analysis, however, is by definition commodity-specific and may ignore food diversity. Prioritizing different facets of food value chains, diets, and nutrition thus involves many potential trade-offs, between delivering nutritious foods, climate-related impacts, and incentives for market-led business models. Nevertheless, interventions in food value chains for nutrition have the potential to address dietary patterns and the nutritional content of foods consumed by vulnerable populations. They can also address the rapid changes that are taking place in the food environment, which are affecting the structure of food value chains, and how particular foods are being produced, delivered, or consumed.

This chapter does not provide details on previous reviews of food value chains for nutrition that have been completed (e.g. Gelli *et al*., 2015; Allen and de Brauw, 2018; Ruel *et al*., 2017). It instead focuses on understanding the supply and demand aspects of food value chains and their relationship to nutrition using a food-systems perspective. It considers the collaborative roles of value chain actors, including producers, consumers, organizations, businesses, and the public sector. Finally, the chapter provides specific examples of interventions that have strived to put food value chains to work for nutrition and the lessons learned.

Why Value Chains?

Nutritious foods are the product of policies, distribution networks, infrastructure for storage, research and technology, information and awareness, and consumer preferences. A number of research studies have noted the failure of these systems to ensure access to nutritious foods due to lack of nutrition awareness, adequate infrastructure, or functioning markets (Maestre *et al*., 2017). Businesses trying to deliver nutritious products in low-income settings also face very specific challenges, including high costs of distribution, food quality requirements, and a lack of food safety regulations, and often require a supportive environment to overcome them.

As food systems change rapidly, understanding how to better leverage the market transformation happening in many countries (i.e. transitions to modern retail outlets and changes in preferences) to target nutrition-related outcomes will be necessary (Gómez and Ricketts, 2013; Popkin, 2014). Interventions that do not take this comprehensive approach risk missing important constraints for long-term sustainability or a critical opportunity for development of food value chains that can support nutrition.

Value chain analysis has been used in rural development for many years (Gelli *et al.*, 2015). Value chain analysis focuses on the value added for different actors along the food chain, and the interactions among them. These actors have different levels of power, and include large companies, the public sector, civil society organizations, small and medium-sized enterprises (SMEs), and informal businesses. Changing value chains to support the production/supply and consumption of more nutritious foods requires shifting the incentives of these actors, reducing or distributing their risks, or changing the preferences and behavior of another set of actors: the consumers.

A market systems approach to categorize value chains for nutritious foods is a fitting way to address the complexities of food systems, since it can identify the root constraints to supply and demand for nutritious foods. Market systems perspectives analyze value chains as being central to the functioning of the market, but also go further to analyze other factors that support the value chain (e.g. roads, energy, information), as well as the rules (laws or social norms) that impact it. These elements all influence how value chains operate, yet many value chain analyses may fail to reflect them (Thorpe and Reed, 2016).

Value Chain Interventions for Increasing Supply and Demand – and Impacting Nutrition

To date, few value chain interventions have shown evidence of improving nutrition (Allen and de Brauw, 2018). Interventions in agricultural value chains have been found to impact production and, potentially, diet diversity, but there exists no evidence of impacts on stunting, for example, or the potential for interventions to scale up (Ruel *et al.*, 2017). Furthermore, evidence indicates that increased agricultural yields or increased income for farmers do not necessarily lead to improved nutrition outcomes (Ruel *et al.*, 2013). This is due to the multidisciplinary nature of the problem. Agricultural programs or policies that aim to improve nutritional status often require complementary initiatives designed specifically to improve nutrition, including, for example, targeting increased consumption of nutritious food (Ruel *et al.*, 2013; Pandey *et al.*, 2016). Issues relating to rapidly evolving food value chains, appearance of new actors within the chains, the inclusion of smallholders in these value chains, and the resulting impacts to nutrition are also still not well understood (Gómez and Ricketts, 2013; Popkin, 2014).

Though the evidence on the contribution of value chains to nutrition is still scant, there exist a number of case studies of interventions targeted to specific needs and gaps in value chains for nutritious products in particular settings (Hawkes and Ruel, 2011; Gelli *et al.*, 2015; Maestre *et al.*, 2017; Nisbett *et al.*, 2017). In recent years, for example, the evidence on the dissemination possibilities and acceptance of biofortified crops has solidified (Manda *et al.*, 2015; Low *et al.*, 2017; Murekezi *et al.*, 2017). Biofortification efforts have been successful in increasing farmers' adoption rates of crop varieties such as iron-fortified beans and millet, as well as vitamin A-fortified maize, cassava, and sweet potato in Asia and Africa. Scaling these varieties up for widespread adoption will require moving beyond a donor-driven effort to one that is accepted by local institutions and supported by accompanying policies and research for increased production efficiency (Bouis, 2012).

In Asia, the Leveraging Agriculture for Nutrition in South Asia (LANSA) program has evaluated the potential of various agri-food value chain pathways to deliver nutritious foods. These include: (i) a large-scale mandatory fortification program in Pakistan; (ii) a private-sector led voluntary fortification of products in Bangladesh and India; (iii) a public–private food distribution scheme in two states in India; and (iv) analyses of the dairy sectors in Pakistan, Bangladesh and Afghanistan (Maestre and Poole, 2018). These analyses show that value chain interventions to improve nutrition do not always achieve the desired results, often facing a combination of supply, distribution, marketing, and consumption challenges. The research finds that while there are multiple pathways to deliver nutritious foods to poor people, there are also important tradeoffs when trying to align business goals and nutrition needs that are not yet well understood.

Promoting a diverse range of healthy and high-value foods, such as fruits, vegetables, legumes, and dairy, can also be an effective way of using value chains to promote nutrition. A recent randomized trial in Senegal leveraging a dairy value chain to distribute a locally produced micronutrient-fortified yogurt and promote optimal infant and young child feeding practices found that, compared with a control group that received only information, children exposed to the intervention had greater increases in hemoglobin concentration. Changes in anemia prevalence, however, were not statistically significant (Le Port *et al*., 2017). This is one of the first studies to evaluate the effectiveness of a nutrition-sensitive value chain intervention. The intervention itself aimed to improve nutrition among pre-school children living in a remote pastoralist population.

For value chain interventions to be successful in addressing food-related challenges, they must have a clear nutrition objective. Recent reviews of various countries in South Asia (Afghanistan, Bangladesh, India and Pakistan) mapping the pathways for agri-food value chain interventions showed that the majority of the value chain interventions in those countries had no specific nutrition outcomes, and within those that included them, nutrition was generally secondary to boosting incomes and employment (Maestre and Poole, 2018).

Success within value chains also requires that interventions alleviate specific dietary constraints that exist in a particular context by addressing the demand or supply for nutritious foods, or both, as seen in Fig. 3.1 (Gelli *et al*., 2015). Using such a typology can help frame the objectives of specific interventions as well as identify the indicators that can be used to measure outcomes (Gelli *et al*., 2015).

Value chain interventions to address low demand

Where there is low demand for nutritious foods, supporting consumer knowledge of a nutritious diet may be the primary objective of a value chain intervention. This approach was taken by Grameen Danone Foods Ltd (GDFL), a social enterprise set up to produce and distribute fortified yogurt to poor and nutritionally vulnerable children in Bangladesh. While the fortified yogurt has been proven to be effective at addressing malnutrition, the business still struggles to ensure that children consume the yogurt frequently enough (three times a week), and to secure the long-term sustainability of the company (Maestre and Poole, 2018).

In situations characterized by low demand, informational campaigns may also be needed

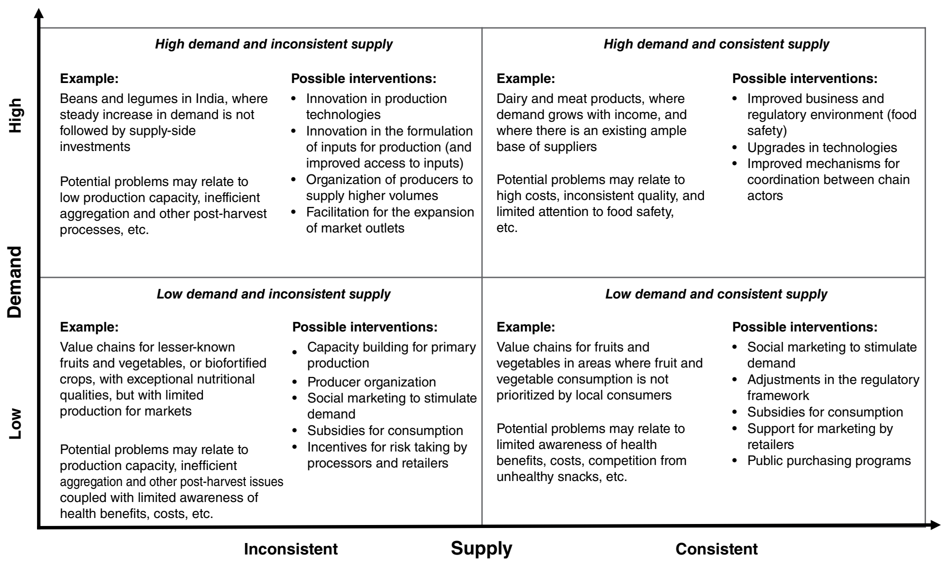

Fig. 3.1. Typologies characterizing value chain interventions (Gelli *et al*., 2015).

to support the development of stronger value chains for nutritious foods. Nutrient-dense foods can be credence goods, or goods for which it is hard for consumers to determine the value, since the 'extra' value addition from a nutrition perspective is not often visible and labeling efforts can result in additional costs (Thorpe and Reed, 2016). In regards to cost, value chain interventions must also consider the drivers of demand, including affordability and acceptability in particular contexts. Governments can use public policy to create public food distribution programs such as the Supplementary Nutrition Programme under the Integrated Child Development Services in India (Maestre and Poole, 2018). As mentioned earlier, this can create a challenge (particularly for low-income consumers) as value chain approaches must be economically viable to offer sustainable change in the supply and demand for nutritious products. Several rigorous evaluations of interventions in value chains to improve diets and nutrition are currently under way, including randomized trials of poultry (Gelli *et al.*, 2017) and dairy value chains (ANH, 2017), and of homegrown school feeding as a market development intervention for smallholders (Gelli *et al.*, 2016).

Value chain interventions to address low supply

In cases where there is demand but low supply of nutritious foods (Fig. 3.1), the objective may then shift to production. Value chain interventions would therefore focus on managing production-related risks, such as through drought- or heat-tolerant seeds, improved control of pests and loss, and irrigation, or on post-harvest processes or other infrastructure for storage or transportation (e.g. cold chain technology). Nutrient-dense crops such as vegetables and animal-source foods are perishable products that can quickly spoil; post-harvest technology can increase the supply of nutritious foods in areas where infrastructure constraints lead to high levels of loss (Allen *et al.*, 2016). Infrastructure to increase distribution is also critical.

Previous research on agricultural value chains for nutrition has focused on different mechanisms through which profitability could be ensured, such as through contracts or improving infrastructure to reduce loss. Working through producers' organizations or providing contracts can be used to shift production to more nutritious crops among smallholder farmers and provide the infrastructure to bring them to the market, increasing incomes. For example, in Senegal, giving women control over contracts to produce and deliver fortified milk products during the dry season showed success (Le Port *et al.*, 2017). Another intervention in Kenya aimed to increase participation in supermarket channels for vegetables, and showed improved calorie and micronutrient consumption due to increases in income and crop production diversity (Chege *et al.*, 2015). Unfortunately, when the added revenue fell under the control of men, the effect on nutrition decreased (Chege *et al.*, 2015).

Cross-sectoral considerations

Influencing value chains to support better nutrition also involves the need to account for complex and confounding factors, including sanitation, water access and quality, women's empowerment, and education, requiring nutrition-related interventions to be multifaceted and adaptive. As the above examples demonstrate, the role of gender in food value chains for nutrition is especially important. Women are typically the caregivers and more likely to spend household resources on health and nutrition (Kumar *et al.*, 2018) (see Chapter 6). However, as key actors within value chains, women also tend to be chronically disempowered, further weakening a key impact pathway between agriculture and nutrition (Rao *et al.*, 2017). Therefore, the role of women in supporting value chains for nutrition should be central, and further research on household dynamics and gender relations with regards to nutrition and caring practices is needed.

Market-based Strategies and the Private Sector

As mentioned previously, interventions in food value chains that work through markets can be potentially more sustainable and scalable in comparison with targeted nutrition-focused interventions. Market access is a critical component of many agriculture–nutrition interventions. For example, a study in Malawi found that farm-production diversity is positively associated with dietary diversity; however, the association is less significant than that for access to markets for purchasing or selling food (Koppmair *et al*., 2017). Proximity to markets can allow higher economic access (through increased incomes from selling production) and physical access to nutritious foods (increased variety of foods available). Similarly, in Ethiopia, increased nutrition knowledge has also been shown to be associated with diet diversity, but this impact is constrained in households with low market access (Hirvonen *et al*., 2017).

A number of studies have called for more interaction with the private sector to support value chains for nutritious foods. The role of the private sector in nutrition has long been debated. There are many who are suspicious of engaging the private sector in any nutrition intervention or policy given incentives (Hoddinott *et al*., 2015). Bridging the incentives of the public and private sectors has indeed proven difficult (Maestre and Poole, 2018). Opponents also argue that businesses are key contributors to overnutrition and the 'nutrition transition' (Popkin, 1998), with households having less time to cook, and companies producing more processed foods, leading to an increased intake of calories from sugars and fats, and to the double burden of under- and overnutrition at individual, household and national levels (Popkin *et al*., 2012; Kleinert and Horton, 2015). At the same time, many others call for a better understanding of the role of markets and the private sector in nutrition to potentially better shape outcomes (Gillespie *et al*., 2013; Ruel *et al*., 2013).

Private sector engagement in nutrition occurs in multiple ways, both positive and negative, partly dependent on the structure of the value chain. Agri-food value chains may be short and simple or long and complex, and, as mentioned, often involve different types of actors across one region or multiple countries, of different sizes. One common approach to leveraging public and private resources is public–private partnerships. An example is a partnership between Nutreal Ltd and a Uganda-based research institute to improve production, processing, nutrition retention, and pest management practices of actors involved in the bean supply chain (Hawkes and Ruel, 2011). At a larger scale, the creation of both the Scaling Up Nutrition (SUN) movement and the Global Alliance for Improved Nutrition (GAIN) are good examples of the development of multi-stakeholder platforms to leverage public and private resources to tackle malnutrition.

Nevertheless, there are still limited assessments for which it is possible to clearly delineate the potential role of the private sector, and its benefits and challenges for value chains for nutritious foods (Hoddinott *et al*., 2015). Examples of public–private partnerships involving procurement for social protection programs, like school meals, are currently being examined rigorously (Gelli *et al*., 2016). A key issue that has arisen in these programs involves the coordination effort required to maintain alignment between the incentives for the different stakeholders in the chain and the public sector priorities.

Using examples from other goods and service sectors, Thorpe and Reed (2016) demonstrated the use of a market-systems approach in identifying constraints to food value chains for nutrition. They noted the importance of consumer information to understand (and value) particular product characteristics, the motivations of value chain actors, and meet the constraints using innovations along the value chain (including product redesign and marketing, co-financing to share risk, overcoming information gaps, and adaptive management). It is also important to consider the informal sector in design and implementation in order to provide nutritious and safe food for rural and low-income populations as well as urban and higher-income groups (Robinson and Yoshida, 2016).

Maestre *et al*. (2017) developed a framework that illustrates the distribution–consumption linkage between the different levels in the food chain from nutrient requirements, through product demand and supply, new product development, firm strategy, the industry or market environment and the distribution systems, and consumption of nutritious foods by vulnerable population groups. They identified three core routes to link different value chain actors, markets and households: changes in food supply, changes in food demand, and changes within the value chain. In this framework, the final outcome is a value chain that delivers nutrient-rich food that, at the point of consumption, is nutritious, safe and consumed in adequate quantities. This outcome will be the result of the nutritious food value chain being sustainable, coordinated and offering incentives to ensure viable business models to the actors who integrate it as well as meeting consumer requirements such as affordability, availability, acceptability, safety, and nutrition awareness. Overall, these supply-and-demand requirements would be affected not only by the value chain actors but also by the consumer and the broader macroeconomic context in which the chain operates. It then becomes relevant for policy-makers and other stakeholders to understand the enabling environment where the chain operates, as well as both the opportunities and the limitations to what the private sector can contribute alone.

There are scant examples of policies aimed at improving the nutrition aims and performance of value chains. Regardless, several countries have begun to put value chain-based approaches into practice. A number of partnerships are ongoing or under development to evaluate mechanisms of addressing the double burden of malnutrition, including the consultative research program, Agriculture for Nutrition and Health (A4NH), a partnership between IFPRI and CGIAR, to evaluate the impact of food prices on obesity and overweight in Latin America. In addition, new research program, Food Industries for People and Planet (FIPP), was launched in 2018 by IFPRI and will focus on all components of the agri-food value chain to increase access to nutritious foods for the global population.

Conclusions

Despite global goals to decrease malnutrition, there remain many challenges in providing access to a nutritious diet for all. Food value chains for nutrition have been the focus of a number of reviews but evidence of their impacts remains limited. Using a systems perspective to look at markets and the role of the private sector in nutrition includes not only the complex relations between multiple actors and trade-offs between often competing objectives, but also the supporting environment in terms of infrastructure (e.g. roads, energy) and the guiding laws and social norms.

Building effective linkages in any value chain that can successfully deliver nutritious foods will require initiatives on multiple fronts, starting with clear nutrition goals (Hawkes and Ruel, 2011). Any policy or intervention must improve the nutritional status of the population, while at the same time providing incentives and capabilities or enforcing regulation to support all types of businesses in overcoming challenges associated with delivering nutritious food. Inevitably, there will be trade-offs in the process. For example, reaching remote rural areas may increase distribution costs, or ensuring that products are safe may require better enforcement of regulations, potentially making the final product less affordable for vulnerable people or less profitable for the business. This is especially true in developing countries where populations are increasingly being impacted by poor diets resulting in the coexistence of both undernourishment and overweight.

The informal sector and local SMEs feature prominently in a majority of food value chains in developing countries, and engaging with them will be critical for long-term sustainability. To be able to tackle the triple burden of malnutrition, the public sector will need to play a key role and establish clear nutrition objectives. Nutrition continues to be a high priority on many government agendas, but given the multiple sectors involved in food value chains, miscommunication regarding the needs and roles of particular actors is prevalent and more care is needed to design context-specific interventions (Warren and Frongillo, 2017). There is also a need to better understand and capitalize on the market transformation that is underway in many countries to better target nutrition-related outcomes by shifting incentives, reducing risk, and changing consumer preferences and behavior. Companies are limited in what they can achieve within the market environment. In order to design and implement effective policies and strategies around value chains, policy-makers need to create an enabling institutional environment, so that they can better shape value chains to deliver nutritious products in a sustainable way, leveraging the capabilities and willingness of all stakeholders involved. With a clear public sector goal, and ensuring that actors work together, these policies can become more sustainable and successful.

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A farmer in Peru displays many different varieties of potatoes. Biodiversity reduces the risk of crop failure due to climate or other shocks, and is also critical to nutrition and health. (H. Holmes/RTB)

4

Biodiversity: an Essential Natural Resource for Improving Diets and Nutrition

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Introduction

Biodiversity is one of the most important natural resources underlying healthy and thriving agriculture and food systems. Without this resource, we would not have the wide range of foods grown across landscapes that feed our increasing demand for varied diets. While the abundance of species around the globe is extraordinary, the loss of those species is devastating. This loss puts the quality and diversity of global diets at risk: that is, diets made up of foods containing energy, macro- and micronutrients that are necessary to sustain life, support physical activity, and attain a healthy body composition. Ideally, these diets should consist of nutrient-dense foods such as vegetables, fruits, legumes, nuts and seeds, whole grains and cereals, dairy, and animal- and plant-based proteins, that are unique to the geographical location and cultural context.

This chapter characterizes the biodiversity on the planet and stresses the importance of biodiversity for agriculture. It then highlights the latest research on the decline in biodiversity and its impact on food supplies, and how biodiversity links to diets. It describes some challenges in ensuring that agrobiodiversity is central to sustainable development. Finally, it identifies the gaps in knowledge that remain and some potential solutions to push biodiversity to the forefront of the 2030 sustainable development agenda.

Definitions and Concepts

Biodiversity and agrobiodiversity

Biodiversity (also known as biological diversity) constitutes the variety of life on the planet including plants, animals, fungi, and microorganisms. The planet's biodiversity is vast. As of 2015, 2 million species of animals, plants, and other kingdoms have been discovered and estimates suggest that another 6 million are yet to be identified, particularly from certain ecosystems such as the oceans (Horton, 2017).

Biodiversity is often defined at three levels (FAO–PAR, 2011):

1. Species diversity: the variety of different species that make up plants, animals, fungi, and microorganisms.
2. Genetic diversity: the variety of genes contained in those plants, animals, fungi, and microorganisms. This variety can be examined between species but also within species.
3. Ecosystem diversity: the variety of habitats on the planet that have different relationships with living and non-living components (like other natural resources including sunlight, water, and soil nutrients).

Agrobiodiversity (also known as agricultural biodiversity) includes all components of biological diversity of relevance to food and agriculture, and all components of biological diversity that constitute agricultural ecosystems, also termed agroecosystems (FAO, 1997). Agrobiodiversity consists of many different species in plant, animal, and other kingdoms. Plant genetic resources include crops, wild plants harvested and managed for food, trees on farms, pasture, and rangeland species. Animal genetic resources include domesticated animals, wild animals hunted for food, wild and farmed fish, and other aquatic organisms (FAO, 2010). Agrobiodiversity also includes microbial and fungal genetic resources.

These three types of genetic resources support the ecosystem services upon which agriculture relies. Services include nutrient cycling, pest and disease regulation, pollination, pollution, erosion and sediment control, maintenance of the hydrological cycle, and carbon sequestration. These genetic resources also support socio-economic and cultural benefits of food and agriculture, because many people depend on genetic diversity for their livelihoods.

While these are often taken in abstract terms, agrobiodiversity is essential to food systems because it serves as the basis of sustaining life – the diverse traits revealed among crops, animals, and other organisms used for food and agriculture, as well as the web of interactions that bind these forms of life at the genetic, species and ecosystems levels. The wide range of landscapes is what diversifies, and thus minimizes, risk. Diversity in landscapes and conservation of agrobiodiversity can serve to protect against crop loss from weather or disease, which could be especially important in the face of climate change. Different species and varieties also offer a large spectrum of nutrients found in foods, as varieties and species contain different nutrient compositions of essential macro- and micronutrients (Swiderska *et al.*, 2011).

Terms such as underutilized, neglected, orphan, minor, niche, wild, local, indigenous, and traditional crops or foods are frequently used interchangeably with biodiversity and agrobiodiversity to describe potentially useful plant and animal species. However, rather than being interchangeable, they are complementary and important food sources that make up the diversity of our food system. Some of these species are strongly linked to the cultural heritage of their places of origin, or are highly adapted to marginal, complex, and difficult environments, or have contributed significantly to diversification and resilience of agroecological niches (Bharucha and Pretty, 2010; Padulosi *et al.*, 2011). Many of these underutilized foods are often not considered 'mainstream' or prioritized in global agriculture agendas, and in some cases they require protection (Fanzo *et al.*, 2016).

Biodiversity hotspots and the importance of biodiversity for agriculture and food supplies

There are some regions with a high number of endemic species that are difficult to find anywhere else on earth. These places have been termed biodiversity hotspots. A hotspot must be home to at least 1500 vascular plants that are endemic, and it must contain 30% or less of its original vegetation, an indication that it is threatened by habitat loss and other human activities (Conservation International, 2018). Conservation International has classified 35 hotspot regions (Fig. 4.1) around the world, comprising just 2.3% of the earth's land surface (Conservation International, 2018). This small total area supports more than half of the world's plant species and 43% of bird, mammal, reptile, and amphibian species (Conservation International, 2018).

Some argue that agriculture 'is one of the greatest enemies of biodiversity, yet agriculture itself depends on biodiversity' (Maxwell *et al.*, 2016). Agriculture can indeed be devastating to biodiversity. The Millennium Ecosystem Assessment concluded that extensive growth of agriculture is a significant driver of habitat loss across landscapes and is the primary threat to biodiversity loss worldwide (Millennium Ecosystem Assessment, 2005), with certain ecosystems such as lowland seasonal forests and grasslands being particularly vulnerable.

> More than two-thirds of Mediterranean forests and temperate forest steppes, and more than half of all temperate broadleaf forests, tropical dry forests, grasslands, shrublands and savannas had been converted to agriculture by the end of the 20th century.
>
> (Perrings and Halkos, 2015)

Yet as discussed earlier, agriculture also depends on biodiversity. In terms of the biodiversity

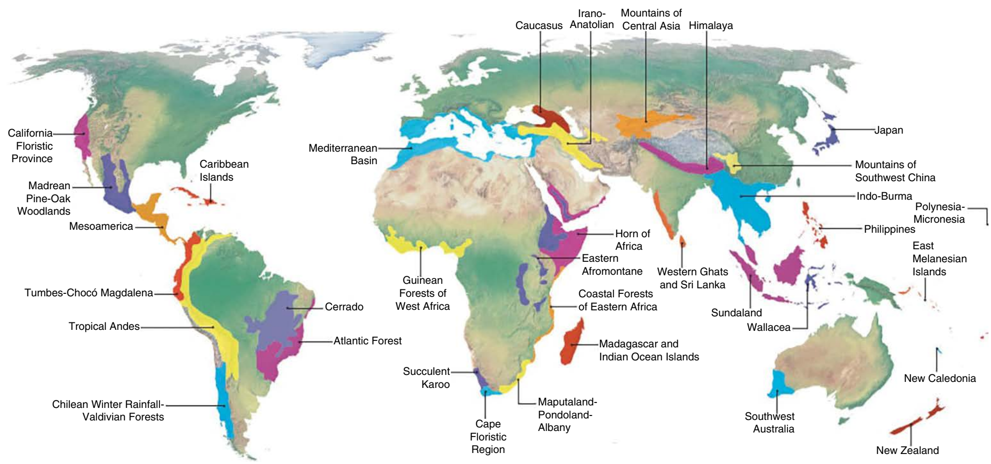

Fig. 4.1. Biodiversity hotspots (Conservation International, 2018).

found within farmed landscapes, there is still much debate on which production systems (large-scale versus small-scale, local versus centralized, mono-cropping versus mixed, or organic versus inorganic) are the most advantageous for maximizing food availability and meeting nutritional needs without wreaking havoc on the environment and natural capital, such as biodiversity.

A study by Herrero *et al.* (2017) found that large farms (> 50 ha), located predominantly in North America and South America, Australia, and New Zealand, produce 75–100% of all cereal, livestock, and fruit in these regions. In contrast, smaller farms (< 20 ha) found in Africa south of the Sahara, South Asia, South-east Asia, and China produce 75% of food commodities globally, and 50–65% of the production volume of major food groups. Very small farms (< 2 ha) in those same regions and located in diverse landscapes produce approximately 30% of most food commodities.

The majority of vegetables (81%), roots and tubers (72%), pulses (67%), fruits (66%), fish and livestock products (60%), and cereals (56%) are produced in diverse landscapes. Plantation-based crops, such as sugarcane and oil palm, are produced in less diverse, large-scale landscapes. Landscapes with more agrobiodiversity produce more nutrients. The diverse production systems of small farms contribute 53–81% of key micronutrients (such as zinc, iron, vitamins A and B12, and folate) and 57% of protein into the global food supply (Herrero *et al.*, 2017). These nutrients are essential for human health, but are often lacking in the diets of vulnerable populations (Fanzo, 2017). Figure 4.2 shows the distribution of key nutrients by farm size and the diversity of foods by nutrients in each region.

What these data show is that the diversity of agricultural production and, hence, nutrient output diminishes as farm size increases. However, areas of the world with higher agricultural diversity produce more nutrients, irrespective of farm size. Efforts to maintain production diversity as farm sizes increase seem to be necessary in order to maintain the production of diverse nutrients, ensure viable, multifunctional, sustainable landscapes; and increase the supply of nutrient-rich foods in the global food system.

Summary of Recent Research

Declining diversity of agricultural production and food supplies

FAO (2010) estimates that of the approximate 300,000 plant species that exist in the world, 10,000 plant species have been used for human food since the origin of agriculture. Out of these, only 150–200 species have been commercially cultivated, with four – rice, wheat, maize and potatoes – supplying 50% of the world's energy needs and 30 crops providing 90% of the world's calorie intake.

During the past 50 years, the composition of countries' food supplies (defined as the number and relative abundances of crops and animal products that contribute to energy, protein, fat and food weight) have become more similar to one another, with variation between food supplies in different countries decreasing on average by 69%. While the availability of energy, protein, and fat have increased in almost all countries' food supplies, the global population more and more relies on a handful of major food crops, mostly wheat, rice, sugar, maize and soybeans (Khoury *et al.*, 2014). Cereal and starchy (and more traditional) root staples such as sorghum, millets, rye, cassava, sweet potato, and yam have become more marginalized. At the same time, agricultural practices are increasingly moving towards intensified monocultures, which improve grain yields in the short term, but put constraints on the biological diversity necessary for high-quality diets (Graham *et al.*, 2007; Negin *et al.*, 2009; Khoury *et al.*, 2014).

Remans *et al.* (2014) found that the nutritional diversity of national food supplies is important for key nutrition outcomes. Controlling for per capita availability of calories and national income, they found a significant negative relationship between the diversity of national food supplies and the national prevalence of child stunting, wasting, and underweight. The prevalence of overweight increased as the calories available per capita increased and was independent of food supply diversity. In low-income countries, the diversity of agricultural commodities produced by a country is strongly associated with its food supply diversity. On the other hand, in middle- and high-income countries, national

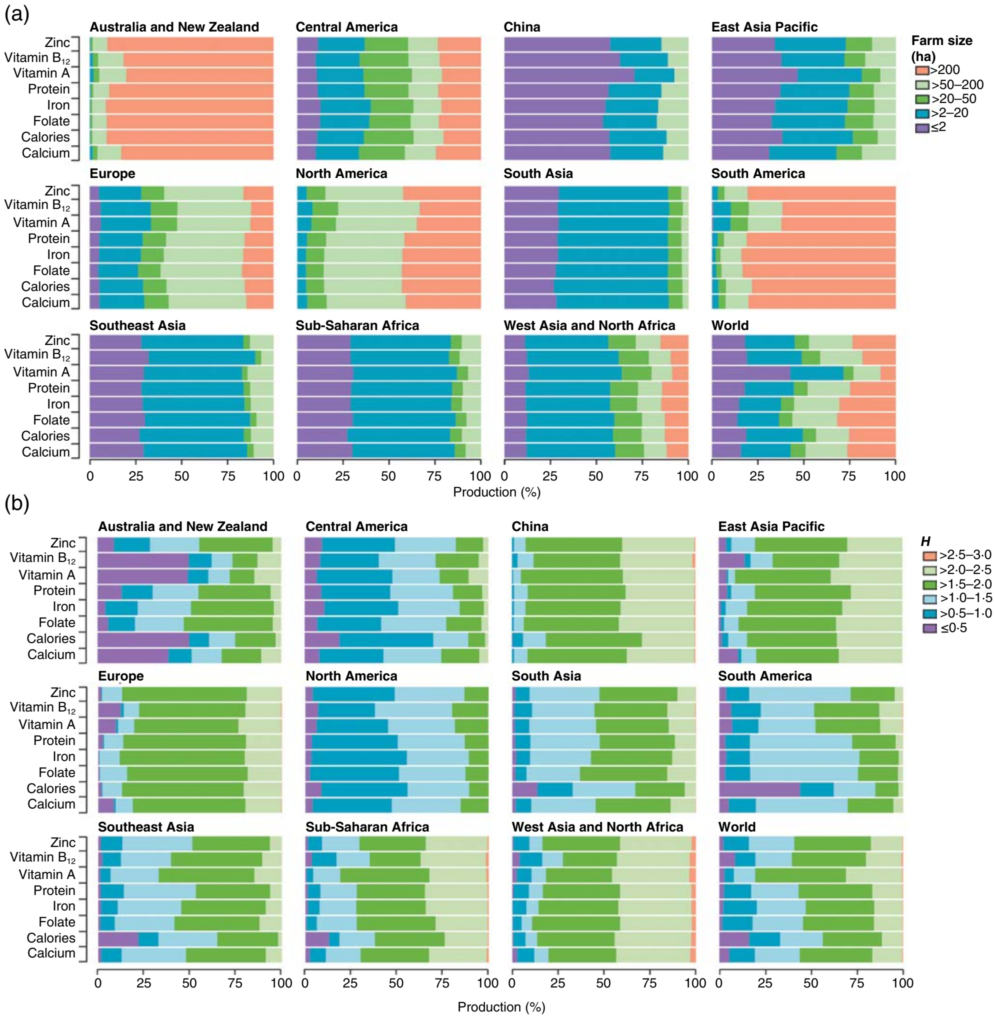

Fig. 4.2. Nutrients produced by farm size and by regions (Herrero *et al*., 2017). (a) Distribution of nutrients by farm size. Very small, < 2 ha; small, 2–20 ha; medium, 20–50 ha; large, 50–200 ha; very large, > 200 ha. (b) Diversity is represented by the Shannon diversity index, *H*, which represents how many different types of foods are produced in a pixel and how evenly these different types are distributed. The higher the Shannon index, the higher the diversity.

income and trade play more significant roles in influencing food supply diversity (Remans *et al.*, 2014).

Evidence suggests that the quality of the food supply also matters for nutritional status outcomes. Data from 1970 to 2010 show that dietary energy from staples and non-staples in the food supply, as an underlying determinant, has contributed to reductions in the global prevalence of stunting (Smith and Haddad, 2015). Another study showed that the prevalence of inadequate micronutrient intakes has declined during the past 50 years in all regions with the exception of Africa south of the Sahara (Beal *et al.*, 2017).

Drivers of loss of diversity in food supplies

There are several reasons for loss in diversity within our food supply. Intensification of agricultural systems due to monocropping of major staple grains and cash crops has led to a substantial reduction in the genetic diversity of domesticated plants and animals in agricultural systems (Khoury *et al.*, 2014; Herrero *et al.*, 2017). Some of these on-farm losses of crop genetic diversity have been partially offset by the maintenance of genetic diversity of seed and animal resource banks since the 20th century as a way of salvaging future sources (Peres, 2016). There are, for example, approximately 1400 seed banks around the world: local banks usually focus on indigenous crops while larger banks, such as the Global Crop Diversity Trust, focus on seeds of plants deemed to have global significance. Under the International Plant Treaty, CGIAR has a legal obligation to conserve and make available 750,000 accessions of crops and trees (CGIAR, 2018).

In addition to the extinction of species, the loss of unique populations has resulted in the erosion of genetic diversity (Millennium Ecosystem Assessment, 2005). Yet the implications of this loss for the biodiversity and quality of the global food supply is scarcely understood or measured from an economic or nutritional perspective. Historically, there have been several high-profile examples of the importance of genetic diversity to staple crops, such as the use of wild progenitors of cultivated species in cross-breeding disease resistance. For example, in the 1970s, scientists discovered a wild teosinte species, an evolutionary cousin of maize, which carried genes for resistance to viral diseases that impact domestic maize; scientists subsequently used these genes to breed virus-resistant maize varieties. Cross-breeding was also used to successfully combat wheat rust for decades until 1999, when rust-resistant varieties in Africa began succumbing to the Ug99 fungus.

Human-related or anthropogenic effects on the environment also threaten the earth's species and ecosystems. These threats are often shaped by migration patterns and the density and pressure of human populations, income and livelihood needs, globalization and, with that, modernization. As incomes and the population grow, the demand for land increases. Demand for land and, in turn, land use changes due to residential and commercial development, agricultural expansion, wetland draining, and forest loss, are associated with declining biodiversity in many parts of the world, including the biodiversity hotspots identified above (Veach *et al.*, 2017). Habitat loss and degradation pose the most direct threats to animals and birds, by decreasing the size of the area that a species can occupy, and its abundance. Tilman *et al.* (2017) suggested that approximately 80% of all threatened terrestrial bird and mammal species are classified as imperiled, and another 21,000 species of plants and other animals are threatened with extinction, by agriculturally driven habitat loss, logging, urbanization, overhunting, invasive species mismanagement, mining, and the establishment of transport corridors.

Demands for certain types of foods are also impacting biodiversity. As incomes increase and people move to urban centers, their dietary diversity improves in gross terms, a shift that also includes an increased demand for animal-source foods. Diets characterized by heavier animal consumption are land-intensive, contribute to diet-related non-communicable diseases, and have been associated with increased emissions of greenhouse gases (Tilman and Clark, 2014). Extrapolating rates of production and use of land for cattle, pigs, and chickens, Machovina *et al.* (2015) found that the consumption of animal-source foods and bushmeat by humans is one of the most powerful negative forces affecting the biological diversity in the world's biodiversity hotspots (Myers *et al.*, 2000). At the same time, it should be noted that even some plant foods have large water and land footprints, depending on how and where they are grown and shipped, highlighting the importance of a life-cycle assessment of food.

There are also economic and social reasons for declines in biodiversity, especially indigenous food species declines. Many indigenous foods cannot compete economically with commodity cereal crops; their producers encounter difficulties in accessing land; there are perceptions of traditional, indigenous or wild foods as being 'food for the poor'; there is a loss of knowledge on how to use or cook these foods; there is a significant work burden to collect, prepare, process and cook these foods; there are inefficiencies in processing and value addition; and there is low market demand or disorganized market value chains (Jaenicke and Virchow, 2013; Kuhnlein *et al.*, 2009; Bharucha and Pretty, 2010).

Linking biodiversity to dietary diversity

Because many poor and undernourished people are smallholder farmers, it is often assumed that diversifying production and conserving biodiversity on small farms would improve dietary diversity within households. However, the impact pathways linking farm production systems to diets and, eventually, health outcomes can be indirect and long, and are still under debate. What does the emerging evidence tell us about these assumptions?

Although evidence gathered to date does not indicate conclusive links, studies have shown positive associations between farm diversity and dietary diversity (Kerr *et al.*, 2007; Figueroa *et al.*, 2009; Murshed-E-Jahan and Pemsl, 2011; Remans *et al.*, 2011; Masset *et al.*, 2012; Jaenicke and Virchow, 2013; Jones *et al.*, 2014; Pellegrini and Tasciotti, 2014; Carletto *et al.*, 2015; Cuc, 2015; Kumar *et al.*, 2015; Olney *et al.*, 2015; Jodlowski *et al.*, 2016). Access to markets and the types of agricultural biodiversity of species grown on farms may also play roles in improving dietary diversity (Carletto *et al.*, 2015; Sibhatu *et al.*, 2015; Koppmair *et al.*, 2016; Fanzo, 2016; Jones, 2017). Nutritional functional diversity (NFD) is a metric that assesses plant species composition on farms as well as the nutritional composition of those plants, thus capturing the diversity of nutrients on farm landscapes. Using this metric, one study performed in rural Kenya, Malawi, and Uganda found no significant correlations at the farm level between the NFD of the crops grown and household dietary diversity. There was, however, a significant association found between the number of foods bought and sold at local markets and household dietary diversity (Remans *et al.*, 2011). Another study using household dietary consumption data in Malawi found that the NFD varied depending on how far households were from markets. Households located farther from markets had lower overall diversity and accessed relatively more of their diversity from home production than did households located closer to markets (Luckett *et al.*, 2015). A third study, also undertaken in Malawi, used a related metric, crop species richness (CSR), to assess the relationship between on-farm diversity and diets. The study showed that dietary diversity was positively associated with CSR and in this case distance to markets did not alter the relationship between CSR and household diet diversity. This latter study showed that on-farm diversity is an important contributor to improving dietary diversity and quality and provides a potential income-generation mechanism to sell those foods in local markets (Jones, 2017).

In many traditional production systems, farm diversity comes from indigenous and often underutilized agrobiodiversity and forests. It is thus assumed that agrobiodiversity is expected to influence the dietary diversity of populations using traditional systems by providing them access to a wider variety of foods. A study in rural DR Congo showed that many of these types of households did not actually utilize the huge diversity of wild edible plants with interesting nutritional characteristics freely available in the forest, the fallow lands, or around their homesteads (Termote *et al.*, 2012). Similar results were found in southern Benin (Boedecker *et al.*, 2014) and in Kenya: in areas with higher agrobiodiverse landscapes, this diversity did not translate into differences in diet diversity for more vulnerable populations such as mothers or their children (Mituki *et al.*, 2017).

Challenges in Leveraging Agrobiodiversity

There are a few core challenges in leveraging the potential of agrobiodiversity in smallholder systems for food and nutrition security. The first of these challenges relates to poverty. It is often assumed that if farmers are given a choice of what to grow on their land, they will choose the option that nets them the most income (Isakson, 2011). At the same time, there is a notion that if some farmers instead choose to conserve biodiversity, as opposed to, say, grow cash crops, they will remain poor, or that they will stave off hunger by planting energy-dense crops (e.g. cassava) (Scherr, 2000; Christiaensen *et al.*, 2011). Barrett *et al.* (2011) articulated four linkages between the conservation of biodiversity and the perpetuation of poverty traps. They are: (i) dependence on inherently limited natural resources; (ii) shared vulnerabilities; (iii) lack of informed adaptive management; and (iv) failure of social institutions. However, the sustainable use of biodiversity, for example within niche-value market chains, could potentially be a pathway to increasing incomes and changing farmers' views on the value of biodiversity. Quinoa, for example, was once a niche crop and is now a cash crop. In such cases, the maintenance, conservation, and sustainable use of biodiversity may be viewed as a viable way of escaping poverty.

The second challenge facing agrobiodiversity is agriculture transformation. As stated earlier, agricultural extensive growth, as driven by the need to provide food, fuel, and fiber to a growing population, is oftentimes responsible for habitat and biodiversity loss (Lopez, 1992; Dasgupta, 1993).

> While growth in the demand for food in high-income countries has generally stimulated the intensification of agriculture, in low-income countries it has frequently led to extensive growth. Specifically, where traditional land tenure and resource access regimes prevail, and where credit markets are poorly developed, increasing demand for food can only be met by land clearance.
>
> (Perrings and Halkos, 2015)

The expansion of land use for agriculture is often undertaken at the expense of other species (both animal and plant).

The third core obstacle relates to planetary boundaries, a central concept in the earth system framework, which aims to define a 'safe operating space for humanity' as a precondition for sustainable development. Once human activity has passed certain tipping points, there is a risk of abrupt and irreversible environmental change (Rockstrom *et al.*, 2009). Humans are rapidly altering their livelihoods and demands for food, water, and natural resources, and as a consequence, ecosystems are being permanently changed. The end result is biodiversity loss at an increased rate, which not only impacts ecosystems themselves but also negatively affects the diversity available to humans within their diets (Vermeulen *et al.*, 2012). These mainly human-induced tipping points have left our planet in a vulnerable state and it will be a significant struggle to regain the biodiversity that has already been lost.

Knowledge Gaps and Opportunities Linking Biodiversity to Human Nutrition

Questions remain on how employing and generating demand for agrobiodiversity can contribute to healthier diets and more sustainable production practices. The knowledge gaps include the following (Fanzo *et al.*, 2016):

- What is the evidence base on how biodiversity in food systems can be managed to increase the livelihoods and incomes of smallholders, as well as improve the nutritional quality and environmental sustainability of diets?
- What are the best practices for 'smart' biodiversity management, such as integrated systems that increase productivity while also improving nutritional value and ecosystem services (CFS, 2016)?
- How can value be added to nutrient-dense niche or traditional crops to make them competitive in the marketplace?
- What are the synergies and trade-offs among dietary diversity, agrobiodiversity, and associated ecosystem functions (Allen *et al.*, 2014; Remans *et al.*, 2014)?
- How do we assess these synergies and trade-offs among income, nutrition, ecosystem, and social outcomes for smallholders as they make farming decisions?
- What other studies (those with rigorous design, robust power, and analytical objectivity) are necessary to assess the impact of household food-production strategies on diets?
- What indicators, metrics, and guidelines are needed to aid decision-making processes at the regional and national levels (Allen and Prosperi, 2014)?

Despite the knowledge gaps, there are many opportunities to improve agrobiodiversity for diets. First, investing in agricultural research and development (R&D) may help governments to identify policies that could be scaled up to improve production practices and supply chains, with the potential to improve diets (Perez and Rosengrant, 2015). Although increases in productivity may have the unintended consequence of making highly processed nutrient-poor foods cheaper, investing in R&D specifically for nutrient-rich crops such as fruits and vegetables, legumes, and neglected foods could lead to improvements in nutrition (Fanzo *et al.*, 2016). Second, by combining nutritional traits with environmental traits, such as tolerance to drought and salinity, as well as to seasonal availability, farmers can begin to see the multiple benefits of their conservation and use (Fanzo *et al*., 2016). Third, improvements in dietary diversity and quality will only be possible if agrobiodiversity is given attention by agricultural extension services (Mituki *et al*., 2017).

At the United Nations Conference on Sustainable Development (Rio+20) in 2012, member states reaffirmed the intrinsic value of biodiversity as the foundation for sustainable development and well-being (UN, 2012, paragraphs 197–204). The Sustainable Development Goals (SDGs) answered that call – and biodiversity is firmly embedded within multiple goals on the 2030 Agenda for Sustainable Development (adopted in 2015). Nutrition is also central to SDG2. Biodiversity is the backbone of our society – without it, we would not have food, fiber, fuel, and the diversity, in all its facets, of the planet. This biodiversity underlies every aspect of diets around the world, from quality to flavor. The central question is how to conserve and sustainably use biodiversity, now and in the future.

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A boy in Brazil eats a meal containing biofortified sweet potato. The country's biofortification program aims to increase iron, zinc and vitamin A levels in diets. (Tarcila Viana/HarvestPlus)

5

Improving Nutrition Through Biofortification

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Introduction: Exploring the Potential of Biofortification

Micronutrient deficiencies, also known as hidden hunger, afflict more than two billion individuals, or one in three people, globally (FAO, 2013). Such deficiencies occur when intake and absorption of vitamins and minerals are too low to sustain good health and development. During the past 40 years, agricultural research for developing countries has helped increase production and availability of calorically dense staple crops, but the production of micronutrient-rich non-staples, such as vegetables, pulses and animal products, has not increased in equal measure. In the long term, increasing the production of micronutrient-rich foods and improving dietary diversity will substantially reduce micronutrient deficiencies. In the short term, consuming biofortified crops can help address micronutrient deficiencies by increasing the daily adequacy of micronutrient intakes among individuals throughout the life cycle (Bouis *et al*., 2011).

Biofortification is the process of increasing the density of vitamins and minerals in a crop through plant breeding, transgenic techniques, or agronomic practices. Biofortified staple crops, when consumed regularly, will generate measurable improvements in human health and nutrition. This chapter provides a critical summary of HarvestPlus-led research and implementation results (2003–2017) and has been developed from Bouis and Saltzman (2017). It discusses delivery experiences and an action-oriented agenda for scaling biofortification to improve nutrition globally. Delivery experiences are discussed from the perspective of HarvestPlus, which leads a global interdisciplinary alliance of research institutions and implementing agencies in the biofortification effort.

Biofortification Research and Development

For biofortification to be successful, the following broad questions must be addressed.

- Can breeding increase the micronutrient density in food staples to make a significant impact on nutritional status?
- When consumed, will the extra nutrients improve micronutrient status?
- Will farmers grow the biofortified varieties and will consumers buy/eat them in sufficient quantities?

To answer these questions, researchers carry out a series of activities in three phases: discovery, development, and dissemination, explained in greater detail below and in Bouis *et al*. (2011).

Discovery

The overlap of cropping patterns, consumption trends, and prevalence of micronutrient malnutrition, as well as ex ante cost–benefit analyses, determine target populations and focus crops. Nutritionists then work with breeders to establish nutritional breeding targets. Breeding targets for biofortified crops are designed to meet the specific dietary needs and consumption patterns of women and children. These target levels take into account the average food intake and habitual food consumption patterns of target population groups, nutrient losses during storage and processing, and nutrient bioavailability, and are updated as more data becomes available (Hotz and McClafferty, 2007).

Plant breeders screen existing crop varieties and accessions in global germplasm banks to determine whether sufficient genetic variation exists to breed for a particular trait, such as high provitamin A content. Initial research has indicated that selection of lines with diverse vitamin and mineral profiles could be exploited for genetic improvement (Saltzman *et al*., 2013). Genetic transformation is an alternative method to incorporate specific genes that express nutritional density.

Development

Plant breeding can increase nutrient levels in staple crops to target levels required for improving human nutrition, without compromising yield or farmer-preferred agronomic traits. For example, several iron beans for Rwanda and the Democratic Republic of the Congo (DRC) fit into farmers' existing crop production schemes. The crop development process entails screening germplasm for available genetic diversity, pre-breeding parental genotypes, developing and testing micronutrient-dense germplasm, conducting genetic studies, and developing molecular markers (fragments of DNA used to identify particularly relevant genetic sequences) to lower the costs and quicken the pace of breeding.

Initial crop development is undertaken at international research institutes to develop varieties with improved nutrient content and high agronomic performance, as well as preferred consumer qualities. Once promising high-yielding, high-nutrient lines emerge, they are tested in several locations across target environments to determine the genotype × environment interaction (G×E) – the influence of the growing environment on micronutrient expression. Robust regional testing enables reduced time-to-market for biofortified varieties. National research partners select the most promising varieties for multi-locational testing over multiple seasons and subsequently submit them to national governments for release. The formal release process varies by country, but in general requires that a variety be grown and evaluated in several different locations (called multi-locational trials) for at least two seasons, and its performance compared with other candidate and widely released varieties, before the national government approves the variety for dissemination. The breeding, testing, and release process can take 6–10 years to complete.

Parallel to crop improvement, nutrition research measures retention and bioavailability of micronutrients in the target crop under typical processing, storage, and cooking practices. Participatory research on consumer and farmer evaluation of biofortified varieties, as well as varietal adoption studies, further informs crop improvement research during the development phase.

Dissemination

Biofortified crops must be formally released in the target countries prior to their delivery to the target populations. By the end of 2017, more than 290 varieties of 12 biofortified crops had been officially released in over 30 countries, and hundreds of varieties of 13 biofortified crops were being tested in over 30 more. Released biofortified crops include vitamin A orange sweet potato (OSP), vitamin A yellow cassava, vitamin A orange maize, vitamin A banana/plantain, iron beans, iron pearl millet, zinc maize, zinc rice, zinc wheat, iron and zinc cowpea, iron and zinc sorghum, and iron and zinc lentils. Additional biofortified crops being tested are iron and zinc Irish potato, iron and zinc sorghum, and vitamin A squash.

Economists lead consumer acceptance, varietal adoption, and seed and grain value chain studies to inform effective, efficient, and targeted delivery and marketing strategies to maximize adoption and consumption of these crops. Delivery experiences are discussed in greater detail in the 'Delivery Experiences' section below.

Comparative Advantages and Cost-effectiveness

The ideal solution for the elimination of micronutrient deficiencies is consumption of appropriate age and activity-level balanced diets that include sufficient quantities of micronutrient-rich vegetal and animal-source foods. Unfortunately, these ideal, balanced diets are often not available (due to seasonality) or accessible (due to price) to many households, especially those in rural areas of developing countries. In the absence of balanced diets, biofortification, fortification and supplementation are three effective interventions that are complementary across time and space.

Vitamin and mineral supplements, in particular vitamin A supplementation, are very effective in improving the micronutrient intakes and the health outcomes of the recipients. Supplementation, however: (i) requires annual mobilization campaigns to sustain reach and coverage, which requires political will, and donor support; (ii) is specific to certain segments of the population (pregnant women or children under 5) and does not reach other members of the household; (iii) requires regular access to clinics or health facilities, or donor-funded child health days held twice per year, where such supplements are given; and (iv) may not protect for a full 6 months in the case of several supplements, such as vitamin A supplementation.

Fortification of commonly consumed food vehicles (like oil, sugar, flour) is a very effective intervention in improving micronutrient intakes. Fortification, however, also has its challenges, in particular: (i) industrially processed, fortified foods are not always easily accessible to rural families, given infrastructure and market access challenges that are common in developing countries; (ii) government mandates are necessary (but often not sufficient) to fortify 100% of the supply of a given fortification vehicle; (iii) proper investment in quality control is necessary to ensure compliance and achievement of target levels; and (iv) incremental costs of fortification are typically transferred to the consumer in terms of higher food prices.

As another food-based approach, biofortification of commonly consumed staple crops is found to significantly improve micronutrient intakes of rural populations in developing countries, as explained in greater detail in the next section. Biofortified foods are self-targeting to rural farm households who tend to consume what they produce, and biofortified staple foods are consumed by all household members. Biofortification delivers nutrients in their natural food matrix, which lessens the likelihood of excess consumption of nutrients. By coupling breeding for nutrients with other desired and essential traits, investment in breeding ensures the maintenance of a robust healthy food supply.

The World Development Report for 1993 (World Bank, 1993), which reviewed many public health interventions, suggested that interventions costing less than US$150 per disability-adjusted life year (DALY) averted (approximately US$261 in 2018 dollars) are highly cost-effective. Ex post results on the cost-effectiveness of biofortification are currently limited to OSP in Uganda. These results show biofortification to cost US$15–20 per DALY saved (HarvestPlus, 2010), while for the same country the cost of vitamin A sugar fortification is US$56 per DALY saved (Fiedler and Macdonald, 2009) and the cost of vitamin A supplementation is US$52 per DALY saved (WHO, 2018).

For other countries where large-scale delivery efforts have recently started or are about to begin, HarvestPlus has calculated the ex ante cost per DALY saved for each context. Peer-reviewed (Meenakshi *et al*., 2010) and HarvestPlus documents (Birol *et al*., 2014) showed that for every country–crop–micronutrient combination, biofortification is cost-effective by the World Bank standard, and that biofortification was significantly more cost-effective than supplementation and fortification for most country–micronutrient combinations analyzed. Even in countries where relatively few DALYs are lost due to micronutrient deficiency, biofortification is expected to have an advantageous benefit–cost ratio (Lividini *et al*., 2017).

Further analyses must be conducted to better understand the optimal portfolio of strategies for improving diets and micronutrient deficiencies. Biofortification is not a 'silver bullet' for the elimination of micronutrient deficiencies, but presents an opportunity for increasing micronutrient intakes of rural households in developing countries.

Biofortified Crops Can Improve Human Nutrition

To develop evidence of nutritional efficacy, nutritionists first measure retention of micronutrients in crops under typical processing, storage, and cooking practices to be sure that sufficient levels of vitamins and minerals will remain in foods that target populations typically eat (Boy and Miloff, 2009; Carvalho *et al*., 2012; De Moura *et al*., 2014, 2015; Mugode *et al*., 2014; Taleon *et al*., 2017). Nutritionists also study the degree to which nutrients bred into crops are absorbed, first by using models, then by direct study in humans in controlled experiments (La Frano *et al*., 2014). Absorption is a prerequisite to demonstrating that biofortified crops can improve micronutrient status, but the change in status with long-term intake of biofortified foods must be measured directly. Therefore, randomized controlled efficacy trials are used to demonstrate the impact of biofortified crops on micronutrient status and functional indicators of micronutrient status (e.g. visual adaptation to darkness for vitamin A crops; physical activity and cognition tests for iron crops). Highlights are discussed below.

Iron crops

Iron nutrition research has demonstrated the efficacy of biofortified iron beans and iron pearl millet in improving the nutritional status of target populations. Biofortified iron beans have been demonstrated to be efficacious in two different populations. In Mexico, after consuming biofortified black beans for 3.5 months, the iron status of primary school children improved (Haas, 2014). In Rwanda, iron-deficient university women showed a significant increase in hemoglobin, ferritin, and total body iron after consuming biofortified beans for 4.5 months (Haas *et al*., 2016). The latter study also found that iron beans had a profound effect on cognition: iron-deficient women who ate biofortified beans experienced improved memory and ability to pay attention (Murray-Kolb *et al*., 2017), key skills for optimal performance at school and work. The study also measured physical performance and preliminary results suggested that improvements in iron status were accompanied by a reduction in time spent in sedentary activity (Luna *et al*., 2015).

Similarly, iron pearl millet was demonstrated to be an efficacious approach to improve iron status in adolescent children in a 6-month study conducted in rural Maharashtra, India. Iron deficiency was significantly reduced and serum ferritin and total body iron were significantly improved in secondary school children who consumed iron pearl millet flat bread twice daily, after only 4 months. Children who were iron deficient at baseline were 64% more likely to resolve their deficiency by 6 months (Finkelstein *et al*., 2015). Results from the same trial indicated that iron biofortified pearl millet consumption also improved cognitive performance (Scott *et al*., 2018) and levels of physical activity (Luna *et al*., 2016).

Finally, a recent systematic review of randomized efficacy trials on iron-biofortified crops reinforced the conclusion that iron biofortification significantly improves iron status – particularly among women and children in poor communities who need it most (Finkelstein *et al*., 2017).

Vitamin A crops

Consumption of OSP can result in a significant increase in vitamin A body stores across age groups (Haskell *et al*., 2004; van Jaarsveld *et al*., 2005; Low *et al*., 2007). The primary evidence for the effectiveness of biofortification comes from OSP, assessed through a randomized controlled intervention effectiveness trial called the Reaching End Users (REU) with OSP project. The REU project delivered OSP planting material to 24,000 households in Mozambique and Uganda from 2006 to 2009, with adoption rates of OSP reaching over 60% among the beneficiaries (i.e. intervention group). In Uganda, the introduction and promotion of OSP over four growing seasons resulted in significantly increased serum retinol at endline for children under 5 years of age in the OSP intervention group who had low vitamin A status at the beginning of the study (Hotz *et al*., 2012a, b). In Mozambique, consumption of OSP by children under 5 significantly reduced the burden of diarrhea, the second leading cause of death in this age group globally; the likelihood of experiencing diarrhea was reduced by 39% and duration of diarrhea episodes was reduced by more than 10% (Jones and de Brauw, 2015). Vitamin A yellow cassava, another root-and-tuber crop, was also demonstrated to be efficacious in an efficacy study conducted in Eastern Kenya with 5–13-year-old rural school children. That study found a modest but significant improvement in vitamin A status, measured by serum retinol and beta-carotene, in the vitamin A yellow cassava versus the control group (Talsma *et al*., 2016).

The beta-carotene in vitamin A orange maize is an efficacious source of vitamin A when consumed as a staple crop. An efficacy study in rural Zambia with 5–6-year-old children showed that, after 3 months, total body stores of vitamin A in children eating orange maize increased significantly compared with those in the control group (Gannon *et al*., 2014). A larger trial conducted with over 1000 marginally malnourished 4–8-year-old children in another rural farming district of Zambia demonstrated that vitamin A orange maize meal consumption increased serum beta-carotene concentrations but did not improve serum retinol (Palmer *et al*., 2016a). In this same trial, visual adaptation to darkness was assessed: among children who were vitamin A deficient at baseline, those who consumed orange maize had greater improvement in pupillary responsiveness than those in the control group, improving their ability to see in dim light (Palmer *et al*., 2016b). Another study in the same region with lactating women showed no increase in mean breast milk retinol concentration among women who consumed vitamin A orange maize, but this issue warrants further investigation (Palmer *et al*., 2016c).

Zinc crops

Brnić *et al*. (2016) compared the absorption of zinc from a biofortified rice variety (22 ppm) and artificially fortified commercial rice (24 ppm) in 16 healthy adults. They found that biofortification of rice was likely as good as post-harvest zinc fortification at tackling zinc deficiency. Rosado *et al*. (2009) and Signorell *et al*. (2015) both found total absorbed zinc from zinc biofortified wheat to be higher than from non-biofortified wheat (the former) and post-harvest fortified wheat (the latter). The evidence on the efficacy of zinc crops is still at its infancy, due to the unavailability of adequate tools for measurement of impact at the levels of zinc which biofortified crops provide. In lieu of such tools, a recent efficacy study investigated the impact of zinc wheat on women's and children's health outcomes in India, and found consumption of zinc wheat to significantly reduce the number of days children had pneumonia and vomiting; and the number of days women had fever (Sazawal *et al*., 2018).

Delivery Experiences

After biofortified varieties have been developed and released, they enter national farming and food systems. By the end of 2017, at least 30 million people were benefiting from biofortified crops. Operations research and monitoring and evaluation of delivery programs continue to add to the evidence that farmers are willing to grow biofortified crops (Asare-Marfo *et al*., 2016; Tedla-Diressie *et al*., 2016) and that consumers are willing to eat them (Chowdhury *et al*., 2011; Meenakshi *et al*., 2012; Birol *et al*., 2015; Banerji *et al*., 2016; Oparinde *et al*., 2016). HarvestPlus and partners are also generating evidence on which delivery and promotion mechanisms have the biggest impact on adoption and consumption, and at what cost (HarvestPlus, 2010). The majority of such evidence is from HarvestPlus's phase I priority countries (including Bangladesh, Brazil, China, Colombia, DRC, India, Nigeria, Pakistan, Rwanda, Uganda, Zambia, and Zimbabwe) where HarvestPlus and national partners are taking the lead in delivery. Phase I countries represent a variety of market environments for biofortified crops, from a primarily commercial, private-sector approach for hybrid crops (e.g. for pearl millet in India and maize in Zambia), to various mixed public–private delivery systems for vegetatively propagated and open-pollinated crops (e.g. cassava in Nigeria, beans in Rwanda and sweet potato in Uganda), to primarily public or informal market systems (e.g. beans and cassava in DRC). Progress in the integration of biofortified crops into the seed and food value chains in these countries is discussed below, using case studies to show how HarvestPlus and its partners have strengthened seed systems, created knowledge and demand, and expanded partnerships to ensure the future sustainability of biofortification.

Vegetatively propagated crops

Vegetatively propagated crops – those for which farmers plant stems, tubers or vines rather than seeds – typically have seed systems characterized by small, informal (rather than commercial) actors. Planting materials are perishable, expensive, and bulky to transport over long distances, and must be replanted within several days of harvesting. The lack of commercial private sector participation creates both a challenge and an opportunity for producing planting materials of biofortified crops like OSP (distributed as vines) and vitamin A cassava (distributed as stem cuttings).

Cassava in Nigeria

In parallel with strengthening the seed system through both community-based and commercial stem production, awareness of and demand for biofortified crops must be created. In the case of vitamin A cassava, extension to farmers was at the forefront of this effort. Initially, free bundles of stems were distributed to farmers, and accompanied by agronomic training and nutrition information. In the following season, farmers who received free stems were required to distribute an equal amount of free stems to two additional farmers, a delivery strategy that reduced costs by almost 95%. This promotional strategy was effective in reaching vulnerable populations who typically do not have market access to improved varieties for planting. It also piqued interest and allowed farmers a low-risk way to test a new product. Many of the farmers who received and planted free stems liked the yellow cassava and are now buying additional stems from commercial traders.

In the early years of delivery, HarvestPlus estimated that about 75% of all biofortified harvested roots were consumed on farm, as many households were not yet producing surplus from the stem packs they received for trial. Diffusion (both within and across farms) and subsequent commercialization were observed in 2016 and 2017 and are likely to increase going forward.

Self-pollinated crops

Self-pollinated crops – those which produce seed true to their parent characteristics – can be replanted year after year. While farmers do need to periodically replace their seed to maintain its desirable agronomic traits, the relatively small annual market for seed typically limits private-sector investment in producing seed for self-pollinated crops. For crops with a low seed rate, like pearl millet, farmers are more likely to purchase seed annually. An open-pollinated variety of biofortified iron pearl millet has been successfully deployed through the private sector in India, where farmers generally purchase seed annually. In many countries, the public sector instead multiplies and distributes self-pollinated seed, and further farmer-to-farmer dissemination is common. Self-pollinated biofortified crops include iron beans, delivered in Rwanda and Democratic Republic of the Congo, zinc rice in Bangladesh, and zinc wheat in India and Pakistan. Delivery has progressed most quickly in Rwanda, where initial public-sector investments have now spurred private-sector interest in meeting growing demand for iron bean seed. Delivery of zinc wheat in India and Pakistan started in 2016 and accelerated in 2017, with numbers of households reached doubling for the former, and tripling for the latter.

Rice in Bangladesh

At the core of the Bangladesh biofortification strategy are rice varieties with attractive agronomic properties and a robust farmer demonstration program. One released zinc rice for the wet season (BRRI dhan 64) is a short-duration variety (100 days as compared with the average 140 days), which allows production of a third crop of lentils or other food between wet and dry season rice crops. Other biofortified zinc rice varieties carry different farmer-preferred agronomic traits, like high height at maturity, which is beneficial for flooded areas in Southern Bangladesh. A robust demonstration program provides farmers a chance to observe these new varieties, as well as training on growing the biofortified rice and the health benefits of zinc.

Seed is produced by both the private and the public sector. A private seed association called SeedNet produces truthfully labeled seed alongside the foundation and certified seed produced by government entities. In order to kick-start the scaling up process, HarvestPlus initially both guarantees a market for a portion of the private-sector production (demand pull) and subsidizes the price for any seed that the private-sector markets directly to farmers (supply push). Free seed is distributed by non-government organization (NGO) and government partners in small seed packs, and all free seed recipients agree to pass on the same amount of seed to three neighboring farmers in the subsequent season. As an increasing amount of zinc rice is available on the market, efforts to increase consumer and miller awareness (demand pull) have increased, including outreach via SMS (text messaging) and programs on local television and community radio channels. As a result of these supply- and demand-side interventions, biofortified seed and food are expected to comprise greater shares of the seed and food systems.

Hybrid crops

Hybrid crops – those for which seed must be replaced each year to maintain the same yield and agronomic traits – offer the most potential for private sector commercialization. While utilizing the private sector for delivery may lead to long-term sustainability, the speed of private-sector uptake is dependent on its assessment of demand. Therefore, the activities of biofortification proponents must focus on targeted demand creation for both farmers and consumers.

Maize in Zambia

Because private seed companies dominate the hybrid maize seed market in Zambia, upon release, biofortified varieties were licensed to companies for commercialization of seed production and distribution. The inclusion of vitamin A maize seed in the Zambian government's Farmer Input Support Programme has further facilitated access to orange maize seed, particularly for vulnerable households.

A central element of the delivery strategy is to use educational and awareness-creation activities to stimulate consumer demand for orange maize products, while engagement with the private sector helps meet growing consumer demand. HarvestPlus also links major grain buyers to farmers and offers test grain to millers and food processors interested in incorporating orange maize in their product lines. Growing interest from farmers and food processors has encouraged increased private-sector seed production.

Building Blocks for Global Delivery

For biofortification to reach scale and be truly sustainable, a number of institutions must become involved in establishing an enabling environment. This includes recognition of biofortification among global normative and regulatory agencies, integration into development policies and programs funded by multilateral institutions, and incorporation into development programs being implemented on the ground, both in target countries and beyond. This enabling environment is essential to encourage the scaling up of biofortified crops and to support national-level actors in various spheres.

Efforts are underway to integrate biofortification into global standards and guidelines, such as the Codex Alimentarius, the food standards-setting agency administered jointly by the World Health Organization (WHO) and the Food and Agriculture Organization of the United Nations (FAO) and recognized by the Sanitary and Phytosanitary Agreement (SPS) of the World Trade Organization (WTO) as its reference organization. Progress toward the development of a definition and standards for biofortification within the Codex Alimentarius continues. A WHO Cochrane review committee was assembled in 2016 to review the scientific evidence and country experiences of scaling up biofortification, and the WHO recommendations for global guidelines on biofortification are anticipated in 2019.

Beyond their individual investments and activities, multilateral institutions, including the World Bank, the African Development Bank, the World Food Programme (WFP), and the WHO, collectively influence national government policymakers and operational partners. The World Bank considers biofortification as a low-cost, high-impact and scalable solution, and is now implementing biofortification projects, including the Multisectoral Food Security and Nutrition Project in Uganda, which is accelerating the scale-up of orange sweet potato and iron beans. As a convener of development partners, the Bank plays an important role in encouraging nutrition-sensitive agricultural approaches, including biofortification, in arenas like the Global Donor Platform for Rural Development. The African Development Bank's new 'Banking on Nutrition' technical partnership is implementing a multisectoral and integrated approach to nutrition interventions, including the integration of biofortified crops. The WFP's Purchase for Progress and School Feeding programs are both very interested in local purchasing of biofortified crops, and partnerships are being developed in several countries, including Rwanda and Zambia in Africa, and Colombia, El Salvador, Guatemala, Honduras, and Nicaragua in Latin America.

While private-sector participation is essential in creating sustainable markets for biofortified seed and foods, NGOs remain important in delivering this nutrition intervention to vulnerable households. The existing global partnership between World Vision and HarvestPlus is an example of how a leading development NGO can incorporate biofortified crops into its existing agricultural programs, linking them to health and nutrition programs. While HarvestPlus provides technical assistance, World Vision takes the lead in delivery. This type of partnership, whereby biofortified crops are integrated into existing agriculture and nutrition projects or included in collaboratively developed new projects, will continue to be important to reach the most vulnerable households, which may also be the most likely to suffer from micronutrient deficiencies. Local NGOs, such as Programme Against Malnutrition (Zambia) and Volunteer Efforts for Development Concerns (Uganda), and international charities, like Caritas and Self-Help Africa, have also been essential partners in reaching vulnerable households with biofortified crops.

Scaling Up and Mainstreaming Biofortification

There is much unfinished business in scaling up and mainstreaming biofortification. In 2018, HarvestPlus entered its fourth 5-year phase and is implementing its new strategic plan, which is designed to lay the groundwork for biofortification to benefit 1 billion consumers globally by 2030. In this new phase, HarvestPlus has commissioned efficacy studies on zinc biofortified crops, as well as effectiveness studies on both zinc and iron biofortified crops. Additional studies are planned to understand the efficacy of biofortification for additional target groups, like adolescents, and on health outcomes beyond micronutrient deficiency status. As part of this new phase, HarvestPlus will work closely with others to further elucidate the comparative advantages of different interventions (biofortification, fortification, and supplementation) across time and location and to establish optimal micronutrient intervention portfolios for scenarios such as global population growth and climate change. This new phase will also analyze, document and make publicly available the data, tools, processes, and the lessons learned from interventions to introduce and scale up biofortification. The ultimate aim of these efforts is to anchor biofortification within the various national and international policies, programs and investments in the agriculture and nutrition nexus.

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Two women harvest leafy vegetables in Bangladesh. Women's higher workloads in agriculture are more consistently associated with higher dietary diversity for mothers and children, but also imply worse child anthropometric outcomes. (IFPRI)

6

Women in Agriculture and the Implications for Nutrition

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Key Role of Women in Agricultural Development, Nutrition and Health

There is now greater urgency to close gender gaps and empower women and girls in the most vulnerable settings. Gender equality is important not only because women have the same rights as men, but also because it sets off a virtuous cycle, paving the way for achieving other development goals, such as reducing poverty and hunger, and improving nutrition and health. Women are often the primary caregivers and food providers for their families. When women benefit, so can their children, their households, and their communities, and these benefits can be passed on to future generations.

But despite widespread acknowledgement of womens' crucial role in the economy, particularly in agriculture, women throughout the developing world continue to face pervasive disadvantages (FAO, 2011; O'Sullivan *et al.*, 2014; Quisumbing *et al.*, 2014b). New data confirm that women own significantly less land than men in Africa (Doss *et al.*, 2015) and Asia (Kieran *et al.*, 2015) and have less say over how household resources are used or allocated (Malapit *et al.*, 2014), yet provide 40% of the labor for crop agriculture in Africa (Palacios-Lopez *et al.*, 2017). This growing recognition of women's importance in agricultural development has now led to more serious efforts to ensure that agricultural development programs are socially inclusive and consider the gendered roles and responsibilities, resources, and constraints of both women and men.

This chapter discusses the role of women in agriculture, and the ways in which their status affects the health and nutrition of their households. It highlights recent literature on the impacts of gendered and nutrition-sensitive agricultural programs. It also goes beyond a singular focus on women to consider the role of gender dynamics in agriculture and nutrition, and why the relationships between men and women are just as important for nutrition. Finally, it considers the ways in which agricultural research and nutrition-sensitive agricultural interventions can be designed so as to achieve better outcomes within nutrition and gender, and how these outcomes can be more accurately measured.

A Theory of Change for Gender, Agriculture, and Nutrition

Gender – the socially determined relationship between women and men – influences agriculture and nutrition in different ways. To understand the role of gender in increasing the nutrition impact of agricultural development projects, one must begin with a credible hypothesis of how the series of positive changes are expected to occur. This theory of change helps bring to focus what the key assumptions are, and whether the expected impacts are achievable if, or when, conditions change. Understanding the pathways also helps identify key milestones that can be measured along the way to monitor whether changes are occurring in the right direction or not.

There is now a broad consensus on the multiple pathways by which agricultural interventions can impact nutrition (Ruel *et al.*, 2017). This framework spans three levels at which processes occur and can be measured: (i) the individual level; (ii) the household level; and (iii) the broader environment (Fig. 6.1). It shows how decisions around agricultural production and household consumption can ultimately influence the health and nutrition of the nutritionally vulnerable populations we care about, particularly women and children. The extent to which the health environment, food environment, and natural environment support behaviors towards better health and nutrition also contributes to the effectiveness of agricultural policies and interventions in improving health and nutrition.

Ruel and Alderman (2013) identified six main pathways through which agricultural interventions affect nutrition:

1. **food access** from own production;
2. **income** from the sale of commodities produced;
3. **food prices** from changes in supply and demand;
4. **women's social status and empowerment** through increased access to and control over resources;
5. **women's time** through participation in agriculture, which can have either positive or negative nutrition impacts for themselves or their children; and

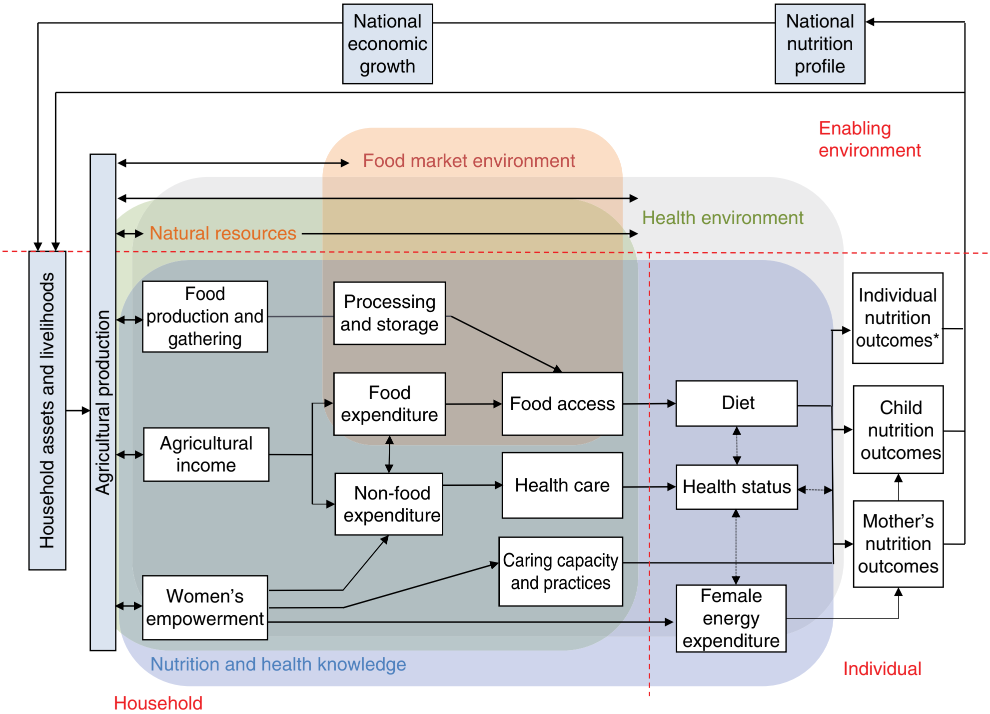

Fig. 6.1. Conceptual pathways between agriculture, nutrition and health (adapted from: Headey *et al*., 2011; Gillespie *et al*., 2012; Herforth and Harris, 2014; and Kadiyala *et al*., 2014).* Individual nutrition outcomes refer to the general population, including women, men, and adolescents (not just mothers and children).

6. women's health and nutrition through engagement in agriculture, which can also have either positive or negative nutrition impacts depending on exposure to occupational health hazards and the balance between energy intake and expenditure (Ruel and Alderman, 2013; Ruel *et al*., 2017).

Pathways 4, 5 and 6 highlight the special role that women have in safeguarding the health and nutrition of children, which helps explain the specific focus that many nutrition programs have had on women and their explicit inattention to men. Throughout much of the world, women are more likely to be caregivers and food providers within their families, so targeting nutrition interventions to women and mothers makes sense. The pathways framework shows that increasing women's social status and control over resources might help direct household spending towards nutritious food and health care, consistent with the positive associations that researchers have found between women's social status and control over resources and child outcomes (Hallman, 2000; Smith *et al*., 2003; Quisumbing, 2003; Yoong *et al*., 2012). Mothers are often targeted for behavior change communication (BCC) interventions that promote optimal infant and young child feeding (IYCF) practices, often with the implicit assumption that they will continue to provide the same level of care regardless of the time intensity of the practices and often without regard for any trade-offs that might arise from competing demands for their time such as other production or livelihood activities and domestic tasks. Women of child-bearing age are also targeted as beneficiaries of nutrition interventions because of their reproductive role: healthy women are more likely to have healthy babies. An improvement in women's health and nutrition is an investment in the health of the next generation.

While these are all valid reasons for targeting women in nutrition-sensitive agricultural programs, this only paints a partial view of the gender equation. Both men and women have important roles in achieving good health and nutrition for themselves and their households, which encompass all six pathways. Gender determines the distribution of all the resources used in agriculture and the distribution of gains from increased agricultural productivity (Doss, 2017): who raises which crops and which animals; how labor and other agricultural inputs are allocated among farm activities; how and by whom agricultural output is distributed and processed along the value chain; who is exposed to which occupational hazards; how food and income are distributed within the household; and which child gets more (or less) access to food and health care (Malapit and Quisumbing, 2016; Quisumbing *et al*., 2017). Focusing on women without paying attention to men and the gender dynamics between them misses important mechanisms that can make or break efforts to leverage agriculture to improve nutrition.

Nutrition Impacts of Gender- and Nutrition-sensitive Agricultural Programs

Nutrition-sensitive agricultural programs, which explicitly aim to improve nutrition through specific nutrition interventions, are often designed in line with women's roles as both agricultural producers and gatekeepers of food and nutrition security for their households (Ruel and Alderman, 2013; van den Bold *et al*. 2013; Ruel *et al*. 2017). These programs can be classified into three modalities: (i) targeting nutrition education to women through BCC; (ii) targeting resources to women, such as assets, inputs, credit, and extension messages; and (iii) organizing women into groups, which serve both as a delivery platform and a way to increase social capital (Quisumbing *et al*., 2017). This section highlights key gender findings from the most recent impact evaluations reviewed by Ruel *et al*. (2017) (see also Chapter 9), organized by the type of activities used by different programs to address gender issues.

Nutrition BCC targeted to women

Nutrition BCC comprises a range of interpersonal, group and mass-media channels and methods that provide program participants with relevant information to encourage and support the adoption of optimal nutrition and child feeding practices and behaviors (McNulty, 2013). Targeting nutrition BCC to women and mothers is perhaps the most common approach used in nutrition-sensitive agricultural development programs. This is consistent with findings by Ruel *et al*. (2017) that inclusion of a strong BCC component to promote optimal diets and child feeding practices is a primary driver for enhanced impacts of agriculture on diets and other nutrition outcomes.

For example, a project promoting biofortified vitamin A-rich orange sweet potato (OSP) has been shown to be effective in Mozambique and Uganda. Project activities were targeted along traditional gender lines: vine distribution combined with agricultural extension services were targeted to men; and BCC and mass media nutrition messages were targeted to women. Hotz *et al*. (2012a, b) documented high rates of farmer adoption and impacts on vitamin A intakes among mothers and young children in both countries, and on child vitamin A status in Uganda (Hotz *et al*., 2012a, b). However, further analysis of the Uganda data (Gilligan *et al*., 2014) found that although women often played a leading role in the decision to adopt OSP, this decision was often jointly made with their husbands. Because of the jointness of these decisions, the current strategy of targeting only women with nutritional training may be missing an opportunity to create an awareness of the benefits of OSP among men (Quisumbing *et al*., 2017).

Resource transfers + nutrition BCC targeted to women

Programs on homestead food production typically combine support for agricultural production with nutrition BCC. The enhanced-homestead food production (EHFP) program in Burkina Faso, implemented by Helen Keller International (HKI), provided inputs and training to women beneficiaries of the program and negotiated with the community for land on which women could establish a village model farm (van den Bold *et al*., 2015). The program had an explicit goal of improving children's nutrition outcomes, targeted to households with women and children in the first 1000 days, and integrated agriculture production activities with a strong nutrition and health BCC strategy (Olney *et al.*, 2015). Beneficiary women received inputs and training for establishing homestead gardens and small livestock rearing. They also received bi-weekly home visits from an older female leader or a health committee member, who trained them on essential nutrition actions, optimal IYCF practices, and provided advice related to adoption of these practices.

Olney *et al.* (2016) found significant improvements in several child outcomes (hemoglobin and anemia, diarrhea, wasting), positive impacts on maternal outcomes (intake of nutritious foods, dietary diversity, underweight), and improvements in several dimensions of women's empowerment, such as meeting with women, purchasing decisions, and health care decisions. The evaluation also documented improvements along the impact pathway, including increases in agricultural production, and household access to, and consumption of, nutrient-rich foods and dietary diversity. In Nepal, where HKI implemented the same EHFP model with a poultry component, Osei *et al.* (2017) found that the program significantly improved household food security and production of eggs and vegetables; several maternal breastfeeding, complementary feeding and hygiene practices; and the use of preventive health services during pregnancy and the first few years of the child's life. Similar positive impacts of EHFP on child anemia were found in the second phase of the Burkina Faso study carried out between 2012 and 2014 (Olney *et al.*, 2017).

A nutrition-sensitive dairy value chain project in northern Senegal, where the population suffers from severe anemia, targeted resources and BCC to women dairy farmers using a different approach. The project distributed a micronutrient-fortified yoghurt (MNFY) as an incentive for increasing milk supply from dairy farmers, coupled with a BCC strategy focused on promoting optimal IYCF practices (Le Port *et al.*, 2017). The MNFY was produced by a local dairy firm that established a contractual arrangement with dairy farmers. Farmers who met the production target were eligible to receive the MNFY, and were instructed to give it to their children aged 24–59 months. The project also included a BCC strategy focused on the promotion of optimal IYCF practices, including use of micronutrient-fortified foods or products for young children. Le Port *et al.* (2017) found that, compared with a control group that received only BCC, children exposed to the BCC + MNFY intervention had greater increases in hemoglobin over the 1-year study period, with larger impacts in boys than girls.

Targeting resource transfers through women's groups

In some cases, targeted resource transfers to women were combined with group-based approaches. Livestock-oriented programs typically fall under this category, and have not traditionally included nutrition interventions (such as BCC) even though they may have nutrition goals such as increasing consumption of animal-source foods, improving household dietary diversity and, in some cases, child nutritional status (Ruel *et al.*, 2017).

For example, Heifer International's community development program in Nepal provided livestock and training to rural women's self-help groups, intended to promote income generation by building women's social capital (Miller *et al.*, 2014; Darrouzet-Nardi *et al.*, 2016). Miller *et al.* (2014) found that, in the Terai areas where program implementation was stronger, the intervention group had significantly increased income per household member (+6,712 vs +2,589 NPR (Nepalese rupees)), improved sanitation practices, better child weight-for-age (WAZ) and height-for-age z-scores (HAZ), and reduced reported sick days compared with control. Household health practices improved in the intervention group from baseline, with more households reporting a water tap in the compound (12% to 28%) and a toilet in their home (40% to 70%), and were more likely to treat drinking water (12% vs 5%) and use soap for hand washing. In all districts, longer participation in the program led to greater improvements in HAZ. A follow-up analysis of child dietary diversity using data from the same study showed that the benefits associated with the program differed depending on agroecological region and season (Darrouzet-Nardi *et al.*, 2016). These studies suggest that the positive impacts on nutrition and diets are mediated through women's empowerment by developing and facilitating women's self-help groups (Darrouzet-Nardi *et al.*, 2016). However, program impacts on women's empowerment were not analyzed.

Women's groups were also used as a delivery platform for a solar-powered drip irrigation intervention in Benin. The intervention aimed to increase crop diversity and dietary diversity security by installing solar market gardens (SMGs) in two villages, working in conjunction with women's agricultural groups that grew vegetables in hand-watered plots prior to the intervention (Alaofè *et al.*, 2016). The evaluation found that the proportion of SMG women's group households engaged in vegetable and fruit production significantly increased by 26% and 55%, respectively, and that SMG women's groups were three times more likely to increase their fruit and vegetable consumption compared with non-women's groups. The study also found that the majority of SMG women's group households used the additional income from the sale of produce to purchase food items that improved the diversity of family diets, including beans, fish and cooking oil.

Discussion

Interventions that paid attention to women's roles in household food and nutrition security tended to focus on women exclusively, resulting in limited attention being paid to men's roles as well as to intra-household dynamics. The lack of attention paid to men's roles in nutrition outcomes may be a missed opportunity, as illustrated by the Uganda OSP evaluation, which has shown that intra-household gender dynamics played an important role in crop choice, child feeding practices, and technology diffusion through information networks in this intervention. A study by Quisumbing *et al.* (2017) found that, where significant, greater equality within households was almost always associated with positive nutritional outcomes. This suggests that nutritional programs that also aim to improve intra-household inequality could have greater impacts than those that do not, highlighting the importance of a household working together towards better nutrition for the family. Targeting women without understanding the broader dynamics of the household and community is likely to miss out on key constraints, opportunities, and impacts (Doss, 2017).

Impact evaluations also rarely address trade-offs between agricultural and nutritional objectives, such as the potential impact on workload from participation in agricultural interventions, or trade-offs between different outcomes. For example, higher incomes could be detrimental to diets if they substitute processed, sugary foods for nutritious ones, as illustrated by some cash and food transfer programs (Quisumbing *et al.*, 2017). Trade-offs could also exist between outcomes for mothers and children. For example, in Nepal and Ghana, studies have found that domains of women's empowerment that were significantly associated with women's diets and nutrition outcomes were different from those associated with children's diets and nutrition outcomes (Malapit and Quisumbing, 2015; Malapit *et al.*, 2015). Similarly, new evidence on associations between dimensions of empowerment and food security and nutrition outcomes in Bangladesh, Cambodia, Ghana, Mozambique, Nepal, and Tanzania found that, indeed, improved nutrition was not necessarily correlated with being empowered across all domains and that different domains had different impacts on nutrition (Quisumbing *et al.*, 2017). This lends support to the hypothesis that increased workloads associated with intensifying agricultural participation may lead to both positive and negative nutrition outcomes. Quisumbing *et al.* (2017) reported that, across the six countries, higher workloads were more consistently associated with higher dietary diversity for mothers and children, but also implied lower women's BMI and worse child anthropometric outcomes. While these observational studies do not allow the same level of causal inference as do well designed and well implemented experimental trials, they have been useful in confirming associations between hypothesized drivers of outcomes, and in generating new hypotheses about potential impact pathways (Ruel *et al.*, 2017). The lack of attention to these potentially harmful unintended consequences remains an important gap in the literature.

Finally, very few experimental studies examine impacts on women's empowerment, even when projects are intentionally designed to influence women's empowerment as a mechanism for improving nutrition outcomes. This is partly due to the relatively recent development of metrics for measuring women's empowerment in the context of agricultural interventions, such as the Women's Empowerment in Agriculture Index (WEAI) (Alkire *et al*., 2013), although new experimental and quasi-experimental impact assessments that use these metrics are now underway.

Designing and Measuring for Success

Recently, there has been encouraging progress in documenting agriculture, gender, and nutrition linkages, both in terms of well designed impact evaluations, as well as rigorous analyses of existing data (Ruel *et al*., 2017). However, there remain important knowledge gaps particularly around how gender issues can be addressed in a way that enhances potential impacts of agriculture on diets and other nutrition outcomes.

An important limitation of nutrition-sensitive agricultural development programs, and the impact evaluations associated with them, is that they tended to target women rather than explicitly addressing gender, and rarely documented impacts on women's empowerment outcomes (Quisumbing *et al*., 2017). Gender- and nutrition-sensitive agricultural programs converge around strategies that attempt to increase women's access to resources and information by targeting women or women's groups, but it is not clear whether any gender impacts are achieved and to what extent these gendered mechanisms contribute to the observed changes in nutrition outcomes.

Even when programs have explicit gender-related goals and strategies, these are rarely accompanied by the collection of appropriate indicators that would document impact on the gender-related goals. In Ruel *et al*. (2017), only two out of the 45 studies reviewed on nutrition-sensitive agriculture specifically documented impacts on women's empowerment outcomes. Programs undertaken by governments and civil society to address gender disparities are rarely rigorously evaluated for their gender impacts (Quisumbing *et al*., 2014a).

Clarity in setting up the goal of the project is the first step: specifically, does the project aim to reach, benefit, or empower women? Simply including women in a program does not necessarily benefit them, and even when women benefit they are not necessarily empowered (Johnson *et al*., 2017). Each of these goals requires different strategies and tactics, and therefore different indicators for monitoring progress. A project that claims to empower women but is only including women as beneficiaries cannot expect to have an impact on empowerment if its activities are insufficient to help beneficiaries make strategic life choices. A project that aims to benefit women must be able to assess how much of the benefits accrue to women compared with men. Similarly, a project that aims to empower women and implements strategies to shift gender norms cannot tell whether its strategies succeeded if it does not collect information on decision making around different aspects of empowerment. This is not to say that all nutrition-sensitive agricultural programs should aspire to empower women. On the contrary, reaching or benefiting women may be perfectly reasonable as an immediate objective in some contexts. But for these programs to succeed, they must be very clear about the program's goals, design a package of activities and interventions that make sense, and then measure the right things to assess impact. There is no rigorous way to tell whether a program is truly effective unless its goals, strategies, tactics and indicators are aligned.

Clarifying whether a program intends to reach, benefit, or empower women is one way to identify which impact pathways are important, and consequently what indicators and metrics should be used to assess gender and nutrition impacts. Although there is currently a lack of consensus on what types of indicators to use for measuring women's empowerment, ongoing research is underway to develop a project-level WEAI as part of the IFPRI-led Gender, Agriculture and Assets Project Phase 2 (GAAP2). GAAP2 is working with a portfolio of 13 nutrition-sensitive agricultural development projects implemented in nine countries to generate rigorous evidence on what dimensions of women's empowerment need to be strengthened to improve maternal and child nutrition.

Conclusion

There is now greater understanding that the global goals for nutrition cannot be achieved without paying attention to women and the role that gender dynamics plays in agriculture. A gender-blind approach is costly, not only because it tends to miss out on important constraints, opportunities, and impacts (Doss, 2017), but also because of the risk of unintended negative impacts of agriculture on nutrition. These can include impacts on women's time for child feeding and care, and the health and nutrition risks associated with exposure to livestock and chicken feces, especially for young children (Ruel *et al.*, 2017). Although more research is needed to understand these risks and how they might be prevented, the division of labor in the household and women's time allocation is central to this question.

Gender roles and norms vary across cultures and contexts, so it is difficult to generalize what types of impacts one could expect for gender- and nutrition-sensitive agricultural interventions.

Addressing such a complex issue requires rigor in the way programs must be designed, implemented, and evaluated. But above all, policy and programmatic efforts to support nutrition-sensitive agriculture need to be grounded in evidence on what works.

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A boy runs through arid farmland in Madagascar. The country narrowly averted famine in 2016 and is taking steps to build resilience to recurring drought. (Jules Bosco/Salohi, USAID)

7

Nutritional Ecology: Understanding the Intersection of Climate/Environmental Change, Food Systems and Health

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The Challenge

The year 2017 was, for the earth in general, the most recent of a string of the 40 warmest years on record (NOAA NCEI, 2017; Whitmee *et al.*, 2015). Global warming is associated with a variety of environmental sequelae involving air, water, temperature and adverse weather patterns affecting land and water resources and ultimately quality of life via changes in habitat and food production. As the earth's human population is expected to reach 9.7 billion by the middle of this century, providing a booming population with healthy diets will call for an estimated doubling of global annual food production (UN DESA, 2017).

The world has not been able to provide sufficient food (either via sustainable local production or distribution of current food supplies) for the poor and most vulnerable people to be able to access healthy, diverse diets. The 2017 UN report on *The State of Food Security and Nutrition in the World* noted that 'After steadily declining for over a decade, global hunger is on the rise again, affecting 815 million people in 2016, or 11 percent of the global population' (FAO *et al.*, 2017). In addition to hunger, the UN report pointed out that malnutrition, caused by unbalanced diets, is likely to affect many more people. For example, iron, iodine, and vitamin A deficiencies affect more than 2 billion people, most prominently women, infants, and children (Bailey *et al.*, 2015).

The UN report highlighted climate/environmental change (CEC) as a primary driver of this recent upturn in the prevalence of hunger and malnutrition, emphasizing that these outcomes involve both the sizes and nutritional qualities of national food supplies. Most importantly, the report emphasized that food insecurity and malnutrition are not simply outcomes of agriculture and trade that affect health, but they are also inputs, or factors affecting the health of individuals and populations that, in turn, impact national agricultural and economic development. This means that CEC has the clear potential to threaten global efforts to assure food and nutrition security, to promote human welfare, and to facilitate national development.

The challenge, therefore, is to address the realities of CEC in ways that sustain the growth of agricultural productivity, guard the nutritional value of food supplies, and promote health and opportunities for developing societies. In meeting this challenge, it will be necessary to consider human nutrition and health as key features of food systems. In that light, this chapter addresses the intersection of CEC, food systems, nutrition and health. It presents the case for how an ecological approach can clarify the relationships of food systems and human nutritional status, and the role of the latter as both an input and outcome of human health. It also argues that considering nutritional ecology in addressing CEC is likely to reduce risks of unintended consequences.

Climate/Environmental Change (CEC)

CEC is profoundly changing the global ecology and quality of life. It is affecting food systems, already challenged by the growing needs of an expanding global population with its record uses of energy, water, and land resources (Whitmee *et al.*, 2015). Rising levels of carbon dioxide ($C0_2$) may reduce the nutritional quality of crops and crop yields, and cause increases in populations of crop pests as well as increases in animal and human parasites and pathogenic microbes. The latter effects would very likely lead to increased use of pesticides and veterinary drugs, which could result in increased toxic residues in foods. Extreme weather events are likely to affect food supplies by impairing trade and other means of food distribution, and by increasing food losses through damage, spoilage and contamination (Ziska *et al.*, 2016).

CEC is also likely to affect the ways and places people live. By increasing sea levels and reducing regular rainfall, CEC is very likely to affect patterns of land use and, hence, population distributions in both coastal and upland regions. Shifts are likely in the location and amount of arable land, shrinking the amount in specific geographical regions, including Africa, South America and Asia, areas already at risk for food insecurity (Zhang and Cai, 2011; Zabel *et al.*, 2014). In addition, CEC is likely to lead to increased accumulation of nitrogen and phosphorus in soils, leading to increased levels in terrestrial ecosystems and wetlands (Hasegawa *et al.*, 2016), losses of plant and animal species diversity (Pauls *et al.*, 2013; Pinkney *et al.*, 2015), and reductions in numbers of insect pollinators (Ellis *et al.*, 2015). Food systems are likely to be affected by pressures related to population changes. These pressures include increased mobilization of organic pollutants and rising numbers of refugees impacted by severe weather events and compromised food, social, economic, and health systems (UNHCR, 2018). The following sections focus more directly on the impacts of CEC on specific aspects of the global food supply.

Impacts on fisheries

The world depends on healthy oceans and their related food systems. However, the world's fisheries and aquacultures face challenges from CEC (FAO, 2016). The World Wildlife Federation (WWF) reported a 49% reduction in marine fish populations between 1970 and 2012 (WWF, 2015). Several factors have been identified as contributing to these changes, most prominently over-fishing: 31% of the earth's oceans are over-fished (FAO, 2016). Other factors include rising water temperatures, ocean acidification, and habitat destruction. In addition, evidence suggests that rising levels of atmospheric CO_2 are causing major changes in marine food chains, leading to reductions in both the quantity and quality of fish for human consumption (Rossoll *et al.*, 2012; Garzke *et al.*, 2016; Golden *et al.*, 2016). These effects may also involve alterations in the amounts and compositions of marine algae consumed by fish (Gomez-Gutierrez *et al.*, 2011).

As the supplies of marine food sources decline, pressures will increase to identify alternative ways of sustaining marine food production, such as through aquaculture or, alternatively, find other sources of protein nutrition. These effects are likely to have greatest impacts on the traditional diets of people living in low-resource settings. The demise of traditional dietary practices will have health implications such as have been documented by O'Brien *et al.* (2017). That report showed a rise in the prevalence of vitamin D-deficiency rickets among indigenous native populations in Alaska whose diets had shifted from the traditional sources of marine-based food to more processed foods. The authors did not address whether these shifts reflected changes in fish availability. Nevertheless, the implications are relevant to the concern about the impact of CEC on fisheries as a major source of nutrition to support health particularly in indigenous populations that rely on fish as part of their traditional diet (Golden *et al.*, 2016).

Impacts on plant food sources

Plant foods are important components of healthy diets. They provide sources of several nutrients not found in most animal tissues, notably xanthophylls, carotenoids, and several vitamins (E, K and C; thiamin, pantothenic acid and folate). CEC is impacting food plants in several ways. Severe weather events such as droughts and floods can destroy food crops. Changing temperature, precipitation and increases in greenhouse gas emissions (GHGE), most notably CO_2 and methane (CH_4), can reduce yields (Donatelli *et al.*, 2015; Kumar, 2016; Lee *et al.*, 2017). For example, research projects that, by 2050, warming could reduce the world's crop production by more than 10%, even under two different scenarios – one with pollution control measures that reduce the surface ozone and another more pessimistic scenario that sees an increase in ozone in most regions (Tai *et al.*, 2014).

GHGE can also impair photosynthesis and reduce disease resistance (Niinemets *et al.*, 2017; Walker *et al.*, 2017). Effects on non-agricultural host plants can lead to reductions in pollinator numbers (Ellis *et al.*, 2015; Brown *et al.*, 2016), and increases in crop pests (Kumar, 2016; Donatelli *et al.*, 2017) which affect yields. Some evidence suggests that CEC can also affect the nutritional value of crops. Ziska *et al.* (2016) conducted a systematic review of the literature attesting to the impact of CEC on the US food system. They concluded that rising atmospheric CO_2 levels were likely to reduce the nutritional value of grains and pulses, by reducing concentrations of protein and at least some essential minerals (e.g. iron, zinc). Another set of researchers (Medek *et al.*, 2017) recently found that under elevated CO_2 concentrations, the protein levels of rice, wheat, and barley decreased by 7.6%, 7.8%, and 14.1%, respectively, leading them to project that by 2050 an additional 148 million people will be at risk of protein deficiency.

Research has also suggested that CEC can lead to reduced levels of iron and zinc in grains and legumes (Ziska *et al.* 2009; Myers *et al.*, 2014, 2015).

CEC may have different effects on crop systems depending on crop and geographic region. For example, Ali *et al.* (2017) reported both increased and decreased yields of four major food crops (wheat, rice, maize and sugarcane) associated with various aspects of CEC (maximum/minimum temperature, rainfall) in Pakistan. Similarly, Zhao *et al.* (2017) found different components of climate change (increased sunlight exposure, reduced humidity, reduced rainfall) to be associated with different effects on spring wheat yields across Inner Mongolia. Thus, decisions about best practices in the face of CEC must take ecological approaches that recognize local contexts, in terms of impact on crop yield, plant nutrient content, and land use patterns/availability.

Impacts on animal-source foods

Compared with plants, foods derived from animals tend to be better sources of biologically complete protein, other essential minerals such as bioavailable iron and zinc, and several vitamins, particularly vitamin B_{12} (which is not found in plants). In addition, the gut microbiome of ruminants such as cattle, sheep, and goats can use plant materials like grasses, maize, and wheat stalks that are not digestible by monogastric species, including poultry, pigs, and humans. This feature enables ruminant animals to harvest nutrients over wide areas. Ruminants and monogastrics also provide manure, which has value as both fertilizer and fuel.

These benefits contrast with other features of animal agriculture. First, many animals, particularly monogastrics and grain-fed ruminants, compete with humans for food/feed grains and grain legumes and, thus, for the acreage required to produce those crops. Second, the gut microbiomes of ruminants produce CH_4, a potent greenhouse gas. A dairy cow, for example, produces 70–120 kg of CH_4 per year. Methane produced from animal agriculture has been estimated to account for 14.5% of the world's total anthropogenic GHGE (Gerber *et al.*, 2013). Livestock can also be, in turn, impacted by CEC; research has shown that animals reduce their feed intake by as much as 25–30% in response to high temperatures (Thornton and Cramer, 2012).

Therefore, decisions about the roles of animal-source foods in human nutrition must consider trade-offs between nutrient production and environmental impact. Such decisions will be facilitated by developing sustainable animal production practices that minimize methane gas emissions (Farchi *et al.*, 2017; Goldstein *et al.*, 2017; White and Hall, 2017), as well as developing alternative sources of protein and vitamin B_{12} (Latunde-Dada *et al.*, 2016; van Huis, 2016; Henchion *et al.*, 2017).

Impact of CEC on biodiversity

Some effects of CEC on food systems are manifest through changes in biodiversity at both macro and micro levels (see Chapter 4). At the macro-ecological level, negative effects on food yields involve loss of pollinators, particularly insects, due to loss of their food species and/or timing of their availability relative to the pollination needs of cultivated crops. These factors have a direct effect on the diversity of agricultural production systems, in turn negatively affecting individuals' abilities to access the diverse diets crucial to good health. In addition, numbers of pest species (Newbery *et al.*, 2016; Ziska and McConnell, 2016; Donatelli *et al.*, 2017) may rise due to degradation of natural habitats. For example, the range of the mountain pine beetle has in recent years expanded to more northern regions, owing to warmer temperatures, leading to a large-scale forest insect blight in North America (Ziska and McConnell, 2016). These effects can be exacerbated by overexploitation of biological resources, pollution, introduction of invasive species and, in the case of oceans, acidification (CBD-WHO, 2015).

At a micro-ecological level, CEC has both direct and indirect impacts on food systems and human health. Negative impacts on the soil microbial ecology or microbiome has direct implications for food systems (Wall *et al.*, 2015; Andriuzzi *et al.*, 2018). CEC impacts the natural regulation of infectious diseases by exposing humans to animal-borne pathogens, and promoting antimicrobial resistance indirectly as a result of antibiotic use in animal agriculture (McCrakin *et al.*, 2016; Helke *et al.*, 2017). CEC also impacts food safety: rises in temperature and changing precipitation patterns can impact the presence of bacteria, viruses, and parasites responsible for food-borne diseases and zoonotic diseases; flooding and droughts can contaminate agricultural soils (Tirado *et al.*, 2010).

Recent findings include evidence that changes in the diversity of animal or human gut microbiome can cause immune dysfunction and increase susceptibility to both infection and, in humans, non-communicable diseases (NCDs) (CBD-WHO, 2015). Shifts in the gut microbiome may be associated with shifting dietary patterns due to changes in dietary quality or nutrition transitions from traditional dietary patterns (Popkin and Gordon-Larsen, 2004; Crittenden and Schnorr, 2017). Additional implications of the intersection of CEC, the gut microbiome and health include increased exposure to antibiotics either directly via medical treatment or indirectly via use in animal production practices (Mie *et al.*, 2017), reduced food and water safety resulting in increased risk of diarrheal disease (Levy *et al.*, 2016), and interactions between microbial diversity, health and nutritional status (Duffy *et al.*, 2015; Shibata *et al.*, 2017).

Nutrition Ecology

The intersections of CEC, food systems, and nutrition are complex (Raiten and Aimone, 2017). Understanding this nexus requires an ontological approach in which the nature of these relationships can be described. One such approach is nutrition ecology, which considers the effects of CEC on the ecologies of food systems and nutrition, including land/water access and quality, air quality, temperature, weather, food safety, human use patterns, and our efforts for their remediation. In application, this approach can not only identify specific diet/nutrition-related outcomes of CEC, but also minimize the risks of programs designed to address impact on global health having unintended consequences on the environment, land use patterns, and so on.

Nutritional ecological approaches acknowledge that food systems are affected by multiple factors, many of which differ according to local contexts (Box 7.1). For example, as discussed earlier, CEC may increase the yields of some crops, but reduce yields of others. Similarly, CEC may increase agricultural productivity in some locales, but reduce it in others. Therefore, effective programs need to be locally indexed and comprehensive, including assessments of land use/availability, crop responses, and food and nutrition security. This is the advantage of using nutrition ecology as a framework from which to analyze CEC.

The biological context

The term 'nutritional status' describes the physiologically active (or potentially active) amount of a given nutrient in an individual's body, and is typically expressed in terms related to statistically derived 'norms'. Individuals are thereby categorized as 'adequate', 'marginal' or 'deficient' with respect to the nutrient(s) analyzed. In practice, this terminology is most useful when referenced to those nutrients that are dietary essentials and are frequently underconsumed (e.g. iron, calcium, magnesium, vitamin A, vitamin D, vitamin E, vitamin C, thiamin, riboflavin, vitamin B_6, vitamin B_{12}, total protein, essential fatty acids). Adequate nutritional status is achieved by having an accessible supply of nutrients in biologically available forms, and by being able to perform the various physiological processes required for their utilization (i.e. ingestion, digestion, absorption, metabolism, transport and integration into dependent biological systems to support growth, development and health). Each of these processes can be affected by the health and developmental stage of the individual. These relationships tend to be reciprocal in nature, many involving feedback regulation. Such scenarios make the ecological approach useful in the evaluation of nutritional status, as well as the safety/efficacy of drugs and other xenobiotics which similarly affect and are affected by nutrition (Raiten, 2011). This approach includes considering the presence of infections or NCDs and/or other environmental exposures (air, food, water).

Box 7.1. Components of the nutrition ecology.

Biological

- Endogenous factors: genetics, developmental stage, relationships between physiological systems
- Health context: infection, NCDs, inflammation
- Microbiome
- Food safety and impacts on health

Natural Environment

- Climate: impacts on weather (severe weather, floods, drought, etc.)
- Impacts of industrialization: effects on water quality, exposure to toxins
- Water: supply, access, sanitation
- Food systems: indigenous foods, monocultures

Socio-economic Environment

- Community
- Social/cultural factors that influence healthcare delivery/practices
- The 'built environment' – physical facilitators/barriers to food security and health
- Household
- Women's roles in childcare, diet (procurement, production), household decision-making, education
- Role of family in development of healthy behaviors
- Economic development context (health disparity)
- Food insecurity and mitigating factors (e.g. HIV/AIDS)
- Access to healthcare/services
- Consumer 'drivers', e.g. disposable household income; increasing demands for western-type dietary patterns
- The 'Nutrition Transition'

Nutritional status affects many physiological systems needed to respond to health challenges, as well as to a community's ability to work and sustain agricultural and economic development. Some of the ways in which poor nutrition can affect human health and performance are as follows:

- Impaired women's health.
- Poor birth outcomes.
- Poor child growth, neurodevelopment.
- Compromised immunocompetence leading to increased disease risk:
  - Diseases (HIV, TB, malaria);
  - Infectious diseases (e.g. Zika) and NCDs.
- Compromised ability to deal with xenobiotics (drugs, toxins).
- Compromised work capacity.

The vicious cycle of food insecurity leading to poor diet, malnutrition and adverse nutritional and health outcomes is depicted in Fig. 7. 1.

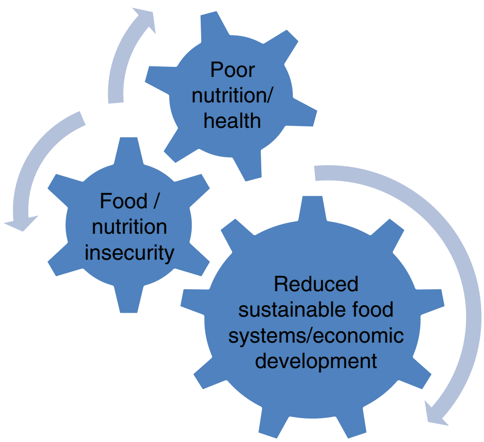

Fig. 7.1. Vicious cycle of food/nutritional insecurity, malnutrition and sustainability.

Superimposed on the daunting challenges of global hunger and malnutrition is a complex global health context. Figure 7.2 depicts the intersection of malnutrition (over/under, 'dual

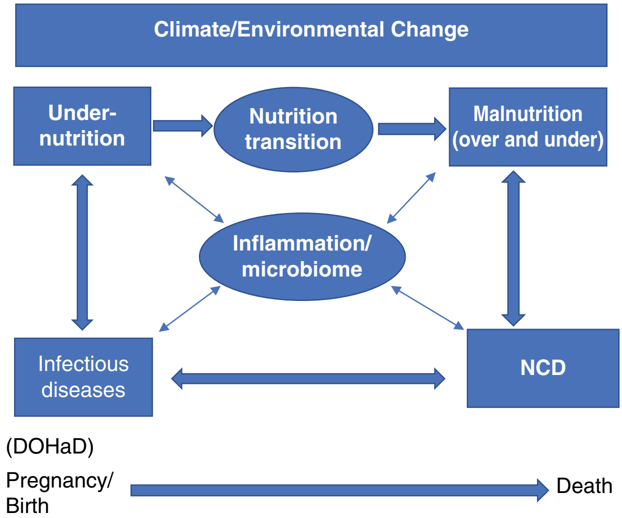

Fig. 7.2. Nutrition, health and CEC (from Raiten *et al.*, 2015).

burden') and diet-associated NCDs (obesity, diabetes, cancer, cardiovascular disease). These problems often occur simultaneously with the persistent burden of such pandemic infections as HIV/AIDS, malaria, tuberculosis (TB), diarrheal diseases along with emerging new infections such as the Zika virus. This global health scenario is depicted in Fig. 7.2.

Implications for nutritional assessment

CEC affects food systems, nutrition and health. An ecological integrated approach is needed to meet the challenge of how to measure these relationships in a rigorous and reliable manner. Traditional, non-ecological approaches that focus solely on food production and availability are likely to be insufficient in this regard. For example, economic and public health perspectives tend to infer nutritional status by measuring access to foods and patterns of food consumption. Individual nutritional status is typically inferred from the biochemical/physiological biomarkers of a relatively few key nutrients. With the absence of other measures reflecting function of specific biological systems (e.g. hemoglobin, growth or grip strength), these approaches provide little information about how apparent nutritional status was achieved or its effect.

The three classes of measures that represent the continuum of assessment from status to function/effect and public health outcomes are summarized in Box 7.2. Which category is used and how it is interpreted will define the expectations regarding their utility. The ability to assess the impacts of CEC on health via nutrition in individuals and populations will necessitate further development and inclusion of each.

The need for an integrated approach is exemplified by the emerging understanding of the importance of inflammation. Nutritional status can affect, and be affected by, inflammation (Raiten *et al.*, 2015). Of practical concern is the impact of inflammation on the interpretation of biomarkers of nutritional status. For example, many biomarkers such as serum ferritin are used to assess status and make decisions about dietary adequacy. Yet the circulating levels of these biomarkers are directly affected by the acute phase response to inflammation, such that their concentrations may be the result of a physiological response to inflammation rather than a dietary insufficiency (Suchdev *et al.*, 2016). Decisions made using these biomarkers and not accounting for the impact of inflammation in their interpretation can result in giving a nutrient like iron to someone who is, in fact, not deficient. Such an interpretation can under certain circumstances place patients at risk for adverse effects (Raiten and Ashour, 2015). Therefore, inflammatory status must be considered as part of nutritional assessment to avert drawing spurious conclusions about nutritional needs, particularly in cases

Box 7.2. Tools measuring nutritional status in ecological contexts (Raiten and Combs, 2015).

Biomarkers:

- Sensitive, specific measures of nutrient exposure, status and function; interpreted in individual biological contexts to distinguish between physiology and nutritional need.
- Reflect the actual 'effect' of a particular nutrient status or intervention.
- Currently, those of nutrient exposure are of limited value; they may detect a unique food component, but few have been validated in practical contexts.

Bio-indicators:

- Sentinel measures of functional change due to changes in nutritional status, disease or intervention (e.g., measures of neurological function, growth, immune function, hematology).
- Lack sensitivity and specificity as sole measures of nutritional status, but have value when used with biomarkers of particular nutrients.

Public Health Indicators

- Non-specific and non-sensitive with regard to nutrition and health.
- Reflect 'system' responses and/or shifts in response to population manipulation.
- Because of their systems context, they are similar to 'bio-indicators'; it may be possible to use nutritional biomarkers as bio-indicators of changes in food/economic systems if expectations about responses are constrained to avoid making decisions out of context.

where biomarkers may reflect a physiological response rather than a dietary imbalance.

Because ecological approaches to assessing nutritional status yield more complete views of local contexts, they are likely to be more useful in understanding and addressing the impacts of CEC and, especially, in reducing risks of unintended consequences of well intentioned interventions. They will also facilitate the inclusion of nutritional status in evidence-based clinical decisions, designing population-based interventions and standards of care, and developing effective policies to address the complex global health context affected by CEC.

Avoiding unintended consequences of interventions

Addressing the food-system impacts of CEC carries the risk of unintended consequences. For example, increasing production of energy-dense staple grains to ameliorate food insecurity related to a changing climate may be associated with increases in obesity risk, micronutrient malnutrition and NCDs if those crops displace pulses and other nutrient-dense crops. The decision to use food or supplement-based interventions intended to prevent or treat iron-deficiency anemia in women and children vulnerable to the effects of CEC may raise the risk of clinical infections, particularly in areas of endemic malaria (Mwangi *et al*., 2017). Economic programs designed to improve household disposable incomes among communities negatively impacted by CEC may lead to a demise in traditional dietary patterns with increasing reliance on commercially processed foods (Popkin *et al*., 2004). Promotion of animal agriculture to address dietary needs for protein and vitamin B_{12} may increase GHGEs. Efforts to create diets that are associated with a low-carbon footprint (i.e. reduced contribution of GHGE) may not meet dietary quality needs (Payne *et al*., 2016). Table 7.1 includes some examples of how an ecological approach might be applied to mitigate the likelihood of such unintended consequences.

Integration to Effective Implementation

CEC is a compelling issue that will require a comprehensive response. Much needs to be done to understand and then accommodate the effects of CEC on food and economic systems to assure their sustainability. A full appreciation of the nature of these relationships requires an

Table 7.1. Nutritional ecological approaches to addressing CEC.

Challenge	CEC impact	Nutritional ecology approach
Improving food security and diet diversity	Changes in crop yields Crop losses due to severe weather Adverse impacts on land, air and water resources Reduced biodiversity Changes in food composition	Understand food consumption patterns Assess health context to determine impacts (reduced intake, altered dietary patterns, effects on nutrient needs, responses to disease and/or treatment)
Addressing micronutrient malnutrition	Increased food insecurity Reduced nutritional values of plant foods Reduced options for biofortification Demises of traditional food practices	Assess food/nutritional security Assess limiting nutrient status Evaluate safety and efficacy of available intervention strategies: assessment of health context (infectious and NCD); relevant biomarkers; therapeutics/toxin exposures
Addressing the 'nutrition transition'	Reduced availability of traditional foods capable of meeting nutritional needs Reduced access to arable land to support sustainable agriculture Increased pressure towards use of processed foods Reduced supplies of traditional animal/marine sources	Assess local cultural trends/traditional diets Assess changes in individual/ household food consumption Nutritional assessment Assess attitudes/beliefs regarding food/dietary patterns including schools Resource constraints at household/ community levels
Ensuring food safety	Rise in food-borne bacteria, viruses, and parasites Contamination of soil and water through extreme weather events	Assess how different actors ensure food safety along food value chains Understand impact of food-borne and zoonotic diseases on human health
Understanding safety and efficacy of 'low-carbon footprint' diets	Efforts to reduce GHGE by producing diets with low 'carbon footprints'	Address capability of such diets to meet nutritional needs Assess economic implications for consumers' sustainability Assess feasibility and sustainability at scale
Meeting dietary guidelines including disease prevention (NCD)	Reduced capacities of food systems to provide healthful balances of fruits, vegetables and animal source foods	Assess agriculture capacity and sustainability of resource use (land, water, economics) Assess economic impact of changes to agricultural practices Assess food quality and acceptability by local consumers
Addressing current and emerging infections	Reduced water/food safety Losses of crop biodiversity Increases in vector-borne diseases	Assess health context with emphases on at-risk groups (women/infants, elderly) Assess water/food safety practices Assess impacts on nutritional status

ecological approach to integrate the biology and health contexts in determining best responses.

Such efforts will benefit from the nutritional ecology perspective, which will facilitate integrating relevant needs and available knowledge into effective and sustainable interventions/programs. This perspective will include the following:

- **Basic biomedical/clinical/plant/animal science research** – to understand the nature and mechanisms of problems related to CEC, disease, toxicology, and all aspects of human growth and development.
- **Knowledge translation** – to devise best practices in clinical assessment and surveillance in identifying problems as they occur in individuals and populations.
- **Interventions** – to address problems in sustainable (environmentally, economically, and culturally) and biologically relevant/efficacious ways. These include nutrition-specific and sensitive interventions including

sustainable food production practices for crops and fisheries.

- **Implementation** – to identify the stakeholders needed roll-out/scale-up effective programs at local/community, national and global levels.
- **Monitoring and evaluation** – to effect timely and appropriate programs/policies with effective and continuous feedback to enable sustained responsiveness to continued change.

That the elements of the nutrition ecology interact in non-linear ways provides both needs and opportunities for their continuous analysis. Therefore, effective data inputs/outputs are needed to monitor and evaluate existing programs/policies to be responsive to environmental and technological changes while minimizing risks of unintended consequences.

Conclusion

The global imperative is complex: to support stable, healthy dietary patterns that are environmentally friendly (particularly regarding GHGE) and are acceptable across a range of culturally diverse settings. Ultimately, the purpose of agriculture is to support human health and well-being. Translating available knowledge about the relationships of diet and health depends on developing evidence-informed guidelines and specific health targets. Following those guidelines and meeting those targets will depend on having sustainable food supplies. The challenge is to accomplish that goal in the face of CEC (Aleksandrowicz *et al.*, 2016; Horgan *et al.*, 2016; Péneau *et al.*, 2017; Perignon *et al.*, 2017; Ridoutt *et al.*, 2017). CEC is exerting profound effects on current and potentially future efforts to feed and care for a hungry planet. Its impacts on land/marine food systems are clear and significant. The effects of CEC are not limited to food systems; they also threaten health. Nutrition serves as the biological variable of health that links these effects. We have laid out a conceptual framework for why and how the elements of the nutrition ecology must be integrated into efforts moving forward to sustain global food production and improve human health in the face of CEC. This approach will facilitate the development of effective responses to one of the most compelling challenges of our time.

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Junk food in a supermarket in the Philippines. The country, like many other developing countries, is facing a rapid rise in obesity. Nearly two-thirds of the world's obese people live in developing countries. (Mark Guim/Flickr)

8

Reshaping Agriculture to Reduce Obesity

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Introduction

The world is faced with a growing obesity epidemic that has critical implications for individual health, household wealth, and social and economic development. In 2013, more than 2.1 billion people, equivalent to 30% of the world's population, suffered from obesity or overweight – the precursor to obesity (Ng *et al.*, 2014). While trend estimations suggest that increases in the prevalence of obesity among adults and children will eventually attenuate in most high-income country (HIC) regions, it will continue at current rates or even accelerate in all low- and middle-income countries (LMIC) regions (Ng *et al.*, 2014; NCD Risk Factor Collaboration, 2017). Already today, almost two-thirds of the world's obese population live in LMICs. Although the prevalence of obesity has been lower among children than among adults, the rate of increase in childhood obesity since the 1980s has been greater than that in adulthood obesity in many countries around the world, especially LMICs (GBD 2015 Obesity Collaborators, 2017).

This chapter provides an overview of the global burden of the growing obesity epidemic and reviews regional trends in macronutrient availability. It then presents drivers of food overconsumption and explains the likely contribution of agriculture to the growing obesity epidemic in LMICs. The chapter concludes by discussing key challenges to reforming agricultural policies for reducing obesity and the potential contribution of food policy research.

Global Burden of the Growing Obesity Epidemic

Obesity considerably increases the risk of several non-communicable diseases (NCDs) such as cardiovascular diseases (like heart attacks and strokes), type 2 diabetes mellitus, and hypertension. According to the 2016 Global Burden of Disease (GBD) study, 72% of all cause-specific deaths worldwide are from NCDs, while the leading causes of total years of life lost are cardiovascular diseases, accounting for 45% of all NCD-caused deaths (GBD 2016 Causes of Death Collaborators, 2017). The global death rate from cardiovascular diseases increased by 15% between 2006 and 2016. Most of the global burden of deaths and disabilities from these NCDs occurs in LMICs mainly because of the large contribution of modifiable risk factors and limited capacities for effective treatment (Wagner and Brath, 2012; Feigin *et al.*, 2016; GBD 2016 Causes of Death Collaborators, 2017). Moreover, the health literature provides robust (suggestive) evidence that fetal undernutrition increases the risk of obesity and associated NCDs later in life (e.g. Barker, 2004; Bhargava *et al.*, 2004; Uauy *et al.*, 2008; Koletzko *et al.*, 2012).

The 2016 GBD study found that high body-mass index (BMI), poor dietary habits, and (likely related) high systolic blood pressure and high fasting plasma glucose rank among the leading modifiable risk factors of attributable deaths and disabilities globally (GBD 2016 Risk Factors Collaborators, 2017). Poor dietary habits refer to consuming unbalanced and unhealthy diets such as diets that are low in vegetables, fruits, pulses, and whole grains and high in red and processed meat, hydrogenated vegetable oils, sugar-sweetened beverages, and sweet and salty snacks. These diets tend to be poor in essential bioavailable micronutrients (minerals and vitamins) and fiber and rich in unhealthy components such as bad cholesterol, saturated and trans fats, and sodium, in addition to being dense in dietary energy (measured in calories). Alarmingly, shifts in patterns of diets toward the consumption of obesogenic foods (which are dense in calories and usually poor in fiber and micronutrients) and nutrition-related NCDs toward obesity-associated diseases in LMICs appear to occur generally at greater speed and earlier stages of economic and social development than in today's HICs at similar development stages in the past (Popkin, 2002).

The growing obesity epidemic has high direct costs for public and private health care budgets, given high treatment costs for associated NCDs (Colditz, 1999; Sassi, 2010). However, the indirect economic costs are often far more important and include costs incurred by reduced labor productivity, work absenteeism, early retirement, disability, and premature mortality (Popkin *et al.*, 2006; Trogdon *et al.*, 2008; Dee *et al.*, 2014). These costs can affect economic growth, especially in labor-intensive economies found in many LMICs. For example, the direct annual costs attributable to overweight and obesity in China are estimated at around US$6 billion and expected to rise by less than 5% between 2000 and 2025 (Popkin *et al.*, 2006). The indirect costs are estimated at about US$44 billion in 2000 and are expected to rise by more than 140% to US$106 billion in 2025. Hence, the total costs of overweight and obesity in China accounted for an estimated 4.1% of the country's gross national product (GNP) in 2000 and an estimated 9.2% of GNP in 2025 (Popkin *et al.*, 2006).

Regional Trends in Calorie and Animal Protein Availability

The obesity epidemic and the associated NCD burden are direct consequences of diets. Rising BMI and increasing prevalence of obesity in a population can be driven either by increasing energy intakes, decreasing energy expenditures, or a combination of both. Using historical data from mostly HICs, Bleich *et al.* (2008) estimated the relative contribution of increased energy intake and reduced physical activity to obesity. The study results showed that the energy imbalance and increasing obesity in recent decades were primarily driven by consuming more calories – at least in the developed world. Similar exploratory studies for LMICs are lacking, possibly because of lack of historical data on physical activity levels. Generally, obesity tends to be less prevalent in rural areas than urban areas, because food options in rural areas are typically less varied and accessible than in urban areas; and physical activity levels are higher due to manual labor-intensive economic activities and lower use of motorized transportation (Malik *et al.*, 2013). The rural–urban differences in dietary and activity patterns tend to shrink with expanding infrastructural development and advancing economic transformation in rural areas (Popkin, 1999).

It should be noted that there is no physiological adjustment process whatsoever to mitigate the effects of energy imbalance on body composition. The portion of the human genome that determines basic anatomy and physiology has remained relatively unchanged since the Stone Age (Eaton *et al.*, 1988; Larsen, 2015; Cordain *et al.*, 1998). Hence, the complex interrelationship between energy intake, energy expenditure, and specific physical activity requirement for current humans remains very similar to that of hunter-gatherers and the first agriculturalists, whose physical activity patterns were very high compared to those of most people today.

The global supply of calories per capita increased by 13% from the early 1980s to the early 2010s (Table 8.1). The three-year average in 2011–2013 exceeded 2800 kcal/day globally and in all HIC-dominated sub-regions and half of all LMIC-dominated sub-regions across the world. Among these sub-regions, the increases in per capita calorie supply from the 3-year average in 1981–1983 were highest in Eastern Asia (29%), Northern Africa (19%), and North America (15%). These sub-regions also showed the largest absolute increase in the number of children and adolescents with obesity (NCD Risk Factor Collaboration, 2017). The trend in these sub-regions are largely driven by one populous country in each of the regions, namely China, Egypt, and the USA, respectively. Egypt and the USA have among the highest prevalence rates of obesity worldwide. Astonishingly, obesity among both women age 20 years and older and girls younger than 20 years is more prevalent in Egypt than the USA (48% and 14% compared with 34% and 13%, respectively) (NCD Risk Factor Collaboration, 2017).

Globally and in most geographical regions and sub-regions of the world, animal protein supply is highly correlated with calorie supply. The global supply of animal protein per capita increased by 36% from a 3-year average of 23.5 g/day in 1981–1983 to 32.0 g/day in 2011–2013 (Table 8.1). Some sub-regions have experienced particularly rapid increases in animal protein supply. For example, during the three-decade period, the animal protein supply increased by more than threefold in Eastern Asia and by more than twofold in South-eastern Asia. Rising consumption of animal products such as red meat, whole-milk dairy products, and eggs increases the risk of nutrition-related NCDs, as these foods are high in saturated fats and cholesterol in addition to protein (GBD 2016 Risk Factors Collaborators, 2017).

Drivers of Overconsumption in Low- and Middle-Income Countries

The rapid increase in food overconsumption and resulting obesity and associated NCDs in LMICs

Table 8.1. Calorie and animal protein supply by geographical regions and correlations (own estimation based on FAO (2017) data).

	Calorie supply per capita			Animal protein supply per capita			Correlation	
	Average (kcal/day)		Change	Average (g/day)		Change	Annual (1981–2013)	
	1981–83	2011–13	(%)	1981–83	2011–13	(%)	Coef.	Sign.[a]
World	***2536***	***2876***	***13***	***23.5***	***32.0***	***36***	***0.99***	***
Africa	*2232*	*2619*	*17*	*13.2*	*16.1*	*22*	0.85	***
Eastern Africa	2061	2167	5	10.2	10.2	0	0.51	***
Middle Africa	1960	2395	22	13.9	15.5	12	0.37	**
Northern Africa	2710	3216	19	15.2	26.5	74	0.96	***
Southern Africa	2785	2925	5	24.9	33.4	34	0.84	***
Western Africa	1934	2687	39	11.8	12.5	6	0.42	**
Americas	*2884*	*3226*	*12*	*43.7*	*51.8*	*19*	0.98	***
Northern America	3185	3654	15	65.9	68.3	4	0.87	***
Central America	2904	2924	1	26.6	36.1	36	0.74	***
Caribbean	2537	2711	7	25.6	25.2	–1	0.73	***
South America	2603	3022	16	29.4	46.3	58	0.97	***
Asia	*2280*	*2768*	*21*	*11.3*	*26.4*	*133*	0.99	***
Central Asia		2794			36.0		0.74	***
Eastern Asia	2373	3057	29	12.6	39.5	214	0.51	***
Southern Asia	2133	2472	16	8.4	14.0	66	0.91	***
South-Eastern Asia	2166	2701	25	11.3	24.3	115	0.99	***
Western Asia	3087	3150	2	26.8	30.9	15	0.59	***
Europe	*3317*	*3366*	*1*	*54.8*	*57.9*	*6*	0.92	***
Eastern Europe	3357	3290	–2	51.1	51.2	0	0.92	***
Northern Europe	3115	3387	9	55.7	61.9	11	0.90	***
Southern Europe	3293	3335	1	50.8	59.0	16	0.32	*
Western Europe	3348	3497	4	65.5	65.3	0	0.08	
Oceania	*3019*	*3201*	*6*	*65.9*	*66.4*	*1*	0.38	**
Australia and New Zealand	3064	3237	6	69.0	69.1	0	0.42	**
Melanesia	2431	2766	14	29.3	30.9	5	0.24	
Micronesia	2772	3041	10	27.3	36.7	34	0.73	***
Polynesia	2621	2932	12	35.2	59.4	69	0.83	***

[a] ***, **, * Correlation coefficient is statistically significant at the 1%, 5%, and 10% level, respectively.

may be largely explained by a combination of three key drivers: (i) economic growth (along with urbanization); (ii) decline in real food prices and relative price changes; and (iii) changes in the global food system (e.g. FAO, 2004; Popkin and Gordon-Larsen, 2004; Popkin, 2006; Prentice, 2006; Swinburn *et al.*, 2011).

Economic growth tends to increase real household incomes, including among the poor. As a consequence, a growing number of people can afford to increase their consumption. Globally, annual GDP per capita has been highly correlated with annual calorie and animal protein supplies per capita (Fig. 8.1). Average GDP per capita growth in LMICs has been positive since 1984 (except for 1991–1992) and has accelerated since 2000.

In addition to increases in total calorie consumption, economic growth is associated with shifts in the composition of total calories consumed (Popkin and Gordon-Larsen, 2004). Globally, as countries have become more urbanized, the share of calories from animal fats and animal protein have drastically increased and the share of calories from carbohydrates and vegetable fats have declined with growing national income; the share of calories from vegetable fat has been constant. At the same national income level, the share of calories from animal fat has increased faster in more urbanized countries than in rural-dominated countries. Among the share of calories from proteins, there has been a proportional substitution of vegetable protein by animal protein (Drenowski and Popkin, 1997).

A decline in real food prices and relative price changes has also been a driver in food overconsumption, obesity, and associated NCDs in LMICs. Global food prices in real terms steeply declined in the 1970s and early 1980s and stabilized at a low level for two decades until the mid-2000s (FAO, 2017). Thus, in addition to rising incomes, declining and stably low food prices helped make food more affordable. Yet, price changes have not been uniform across foods (Delgado, 2003). For example, the real prices of the most common cereals (wheat, maize, and rice) declined by about 50% globally between 1970–1972 and 1996–1998 (Fig. 8.2). The real beef price dropped by 68% and the real milk price declined by 40% globally during this 25-year period. Comparable global price data for vegetables and fruits are unavailable, because vegetables and fruits commonly consumed locally are hardly traded globally. However, changes in domestic real prices of vegetables and fruits can be expected to be nowhere near the declines in (domestic) real prices of cereals and animal products. These relative price changes incentivize consumers to increase their consumption of the cheaper food items and partially substitute (relatively) more expensive food items. Thus, the costs of a diet dense in calories (sourced mainly from staple foods, mostly cereals) and rich in animal protein (sourced mostly from meat) declined rapidly throughout the 1970s, 1980s, and 1990s, whereas the costs of a diverse diet rich in a variety of essential micronutrients may have declined only marginally, if at all.

Changes in the global food system have also played a part in the rise in obesity. The integration of LMIC economies into the global food system through trade liberalization and opening of domestic markets for foreign investors has led to a rise in imported, highly processed, and obesogenic foods and beverages such as fast food, sugar-sweetened drinks, and fatty and salty snacks, often provided by multinational companies (Hawkes, 2005; Rayner *et al.*, 2006; Swinburn *et al.*, 2011). For example, Coca-Cola offers nearly 3900 beverage products in over 200 countries (Coca-Cola, 2018) and McDonald's has more than 36,000 restaurants in over 100 countries (McDonald's, 2018). Many local restaurants and chains have attempted to copy these American fast-food models and their products (Popkin, 2006). The consumption of obesogenic foods and beverages has been aggressively advertised in LMICs through global mass media and roadside billboards, among others. Evidence suggests that children's exposure to obesogenic food and beverage advertisements on television is linked to excess body weight (Lobstein and Dibb, 2005; Lobstein *et al.*, 2015). Globalization and technological innovations (in communication and logistics, for example) in combination with urbanization and affordable motorized transport have also contributed to the rapid spread of multinational and local supermarkets and hypermarkets (Reardon *et al.*, 2003; Mendez and Popkin, 2004). Evidence from urban Kenya, for example, suggests that shopping in supermarkets increases adults' BMI and the risk of overnutrition-related NCDs (Demmler *et al.*, 2017, 2018).

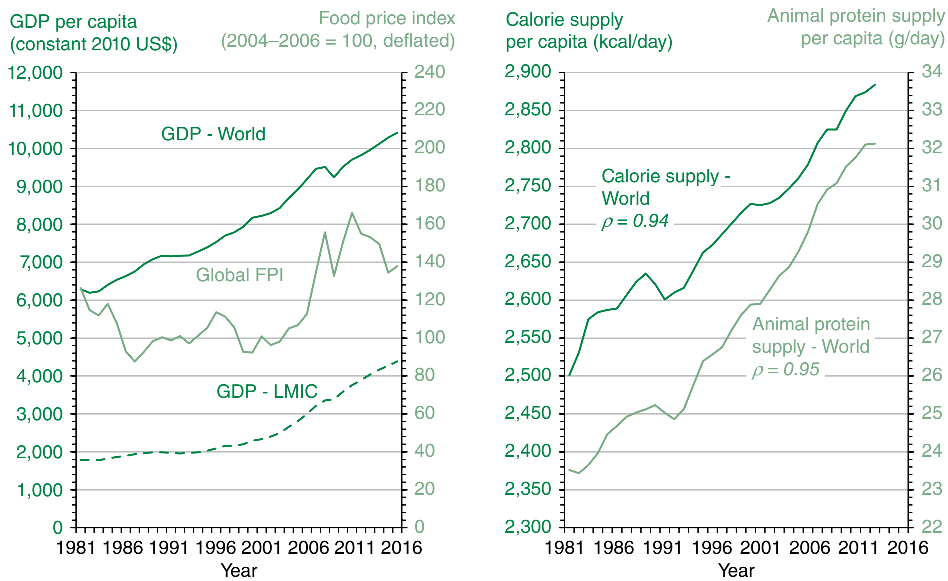

Fig. 8.1. Global economic growth, food prices, and calorie and animal protein supply. Own representation based on World Bank (2017) and FAO (2017) data (ρ = coefficient of correlation with GDP per capita – World).

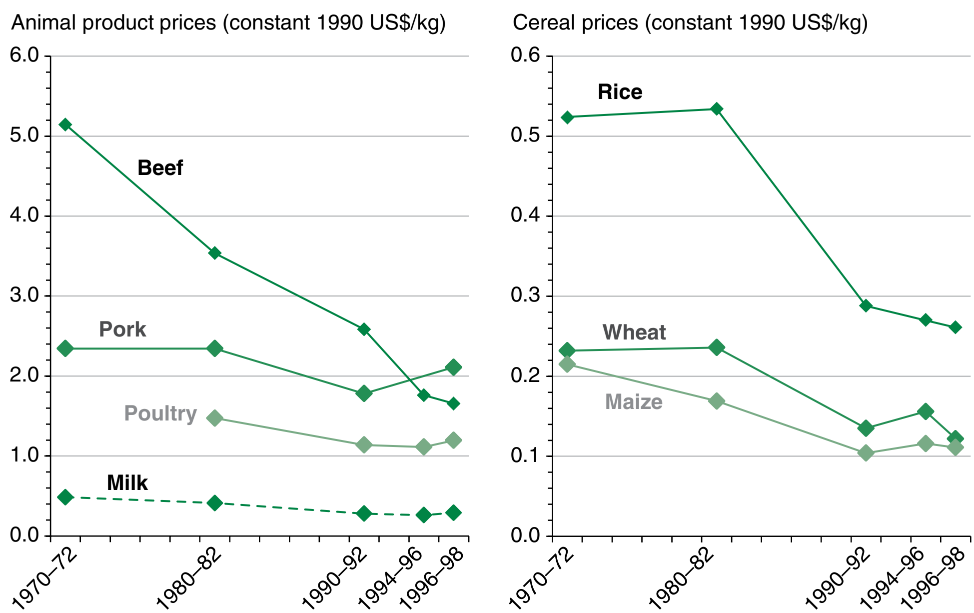

Fig. 8.2. Global prices of cereals and animal products in real terms. Own representation based on data from Delgado *et al*. (2001).

Agriculture's Contribution to the Growing Obesity Epidemic in Low- and Middle-Income Countries

Agriculture and particularly the agricultural and technological revolutions of the late 20th century have likely contributed to the growing obesity epidemic in LMICs in at least four ways.

First, agricultural productivity growth, most notably thanks to the Green Revolution, has contributed to – but has not driven – overall economic growth. Agriculture's average value added to GDP in LMICs steadily declined from around 30% in the late 1960s to around 23% in the early 1980s and below 10% in the late 2000s (World Bank, 2017). Nevertheless, improved agricultural technologies and practices have substantially increased yields of staple crops, especially of the most common cereals, and also led to increased farming incomes (Evenson and Gollin, 2003; Pingali, 2012).

Second, increases in agricultural productivity and outputs have reduced and stabilized real food prices and hence lowered the overall costs of diets for the wider population, as discussed earlier. As productivity gains have differed across crops, so have the rates of price reduction. For example, average yields for all LMICs rose 208% for wheat, 157% for maize, 109% for rice, 78% for potatoes, and 36% for cassava between 1960 and 2000 (Pingali, 2012). These yield increases have not translated into proportional consumer price reductions partly because maize (in addition to soybean) and, to a lesser extent, wheat are also the most important livestock feed grains. The reduction in producer prices for these grains has been partially transmitted into the sharp declines for animal products over past decades (Fig. 8.2) (Delgado, 2003).

Third, agricultural mechanization and increased affordability of motorized transport have reduced the physical workload of farmers and shortened the worktime of farming and agricultural marketing activities (Prentice, 2006; Swinburn *et al.*, 2011). Time savings have been devoted partly to increased leisure time dominated by sedentary activities. These shifts in farmers' physical activity patterns have reduced their energy expenditures, though data on the contribution of agricultural mechanization to energy use is not available.

Fourth, and most critical, the agricultural and food policy environment and especially distortions to agricultural incentives due to government actions in both HICs and LMICs have likely contributed to the growing obesity epidemic in LMICs (Schäfer Elinder, 2005; Hawkes *et al.*, 2012, 2015). Policies that promote directly the production of specific crops or livestock products, such as input subsidies and output price supports, affect domestic food supply and (relative) food prices to which consumers' food demands respond. Similarly, policies that promote agricultural technology adoption, mechanization, and irrigation infrastructure – even if they are non-product-specific or distortive – have differential effects on food production and relative food prices, because improvements in these production factors tend to benefit the production of specific crops or livestock and its scalability. Among food products, agricultural subsidies and other agricultural support policies have mainly been targeted to promote the production of the most common cereals (wheat, maize, rice) and meat and dairy products (Anderson, 2009). Other non-agricultural interventions that nevertheless impact agricultural outputs and consumer food choices include measures at the country's border (such as import or export taxes, price support, and quantitative restrictions) and measures in domestic food markets (such as food price subsidies and taxes and food assistance programs). Agricultural input subsidies, output price protection, and import taxes and restrictions were popular policy instruments to facilitate the Green Revolution in Asia and Latin America and hence to achieve the agricultural productivity gains in past decades mentioned above (Pingali, 2012). Finally, agricultural policies in large exporting countries may also affect food supply and pricing in importing countries by influencing world market prices and exploiting bi- or multilateral trade agreements (such as in the case of European Union's exports of poultry and dairy products to African countries).

Distortion to Agricultural Incentives and Consumption Effects

From the early 1960s to the early 1980s, farmers in LMICs were increasingly taxed directly through taxes on exportable goods and, more so, indirectly through the effects of current national account deficits and industrial protection policies (Krueger *et al.*, 1988). This trend gradually reversed and, since the mid-1990s, resulted in positive aggregate support to farmers (Anderson *et al.*, 2009). In HICs, aggregate support to farmers rose steadily from the 1950s to the early 1990s, before declining, especially when world food prices shot up (Anderson *et al.*, 2009). Nevertheless, government support to farmers has remained much higher in HICs than LMICs.

Anderson and Valenzuela (2008) and Anderson and Nelgen (2013) measured national annual distortions to agricultural incentives for all major agricultural products using the nominal rate of assistance (NRA) – the percentage by which government policies have raised gross returns to farmers above what they would be without the government's interventions (or lowered them, if the NRA is less than zero) (Anderson *et al.*, 2009). Unfortunately, consistent national time-series data are unavailable for this analysis.

Figure 8.3 presents NRA estimates for main foods for LMICs in Africa, Asia, and Latin America and Caribbean, altogether and by region, and for HICs. The selected foods are the top eight agricultural products with the highest gross subsidy equivalent from 1980 to 2009. The NRA by country group is derived from annual, country-level estimates and should be interpreted as averages for groups of selected, important countries rather than regional averages.

Figure 8.3 shows that the eight agricultural products with the highest gross subsidy equivalent globally include the most common cereals (wheat, rice, maize), sugar, and animal-source foods (poultry, pork, beef, milk). Although average NRAs for all eight foods in HICs were considerably lower in the 2000s than the 1980s and 1990s (except for pork), they remain much higher than the respective average NRAs in LMICs. Throughout the 1980s, 1990s, and 2000s, the NRAs in HICs were highest for rice, sugar, and milk. HIC exports of the supported products to LMICs have distorted the prices in the importing LMICs, if they have no HIC NRA-equivalent import taxes in place. Hence, agricultural subsidies and other support measures in HICs have likely contributed to reduce (relative) prices of these foods faced not only by their own populations but also by the LMIC populations.

In LMICs, the shift from overall discrimination against agriculture up to the 1980s to positive aggregate support to farmers since the 1990s was partly driven by reversing agricultural disincentives for the production of the main domestic staple food crops and pork in Asia and Latin America and Caribbean and sugar production in Latin America and Caribbean due to fundamental changes in national agricultural and trade policies (Fig. 8.3). Average NRAs for sugar increased from the 1990s to the 2000s in all three LMIC regions. In contrast, average NRAs for milk were considerably lower in the 2000s than the 1980s and 1990s in Asia and Latin America and the Caribbean and even negative in the 1990s and 2000s in Africa. The largest government support over the three-decade period was received for the production of sugar in Africa; beef, milk, and sugar in Asia; and milk in Latin America and the Caribbean. However, the (positive) average distortion in all three regions was far below that in HICs for any of the eight foods and during any of the three decades (except for beef in Asia).

Government support for producing staple foods, sugar, and animal-source products such as input subsidies and output price protection incentivizes farmers to increase production of these products relative to non- or less supported foods such as vegetables, fruits, and pulses. This tends to translate into lower prices of the supported foods absolutely or relative to other foods. Consumers, particularly the poor, respond to these price signals by consuming more of staple foods, sugar, and – if at all affordable – animal-source foods and less of more nutritious foods such as vegetables, fruits, pulses, and fish, increasing the risk of obesity and insufficient dietary diversity. A typical case is Egypt, where input subsidies and output price protection for the production of main staple crops (wheat, maize, rice) and sugarcane also serve to supply the enormous national food assistance program at low costs. Findings from a recent study suggest that the program contributed to the extreme prevalence of obesity likely by lowering the costs of a calorie-dense diet relative to a more diversified diet (Ecker *et al.*, 2016).

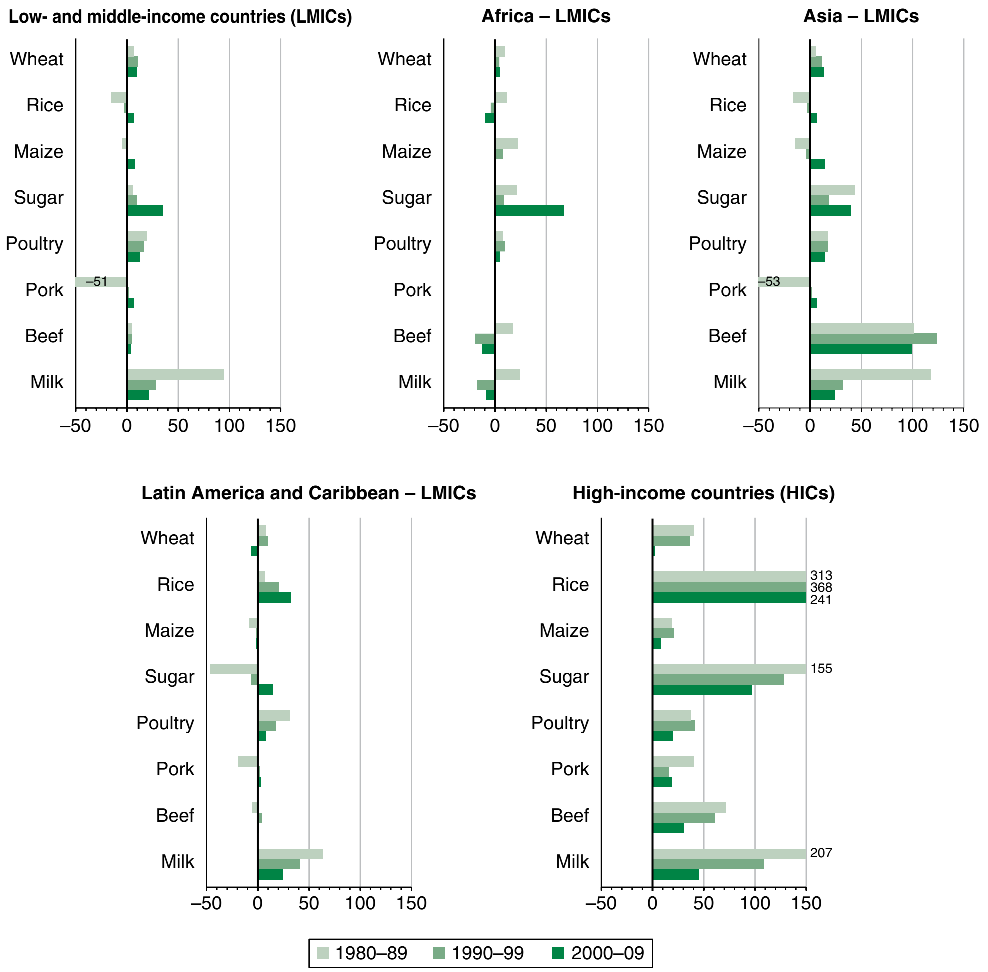

Fig. 8.3. Decade-average nominal rate of assistance (NRA) by region. Own estimation based on data from Anderson and Nelgen (2013). (The country samples partly vary by product. This list of included countries can be received from the author upon request.)

Conclusions

Reforming agricultural policies in both HICs and LMICs to reduce or ultimately eliminate distortions to agricultural incentives that tend to lower the costs of a calorie-dense and animal protein-rich diet relative to a more diversified diet is likely to be an important contribution to alleviate the growing obesity epidemic in LMICs. Many of the agricultural policies in LMICs that promote staple food and livestock production for household food security and national food self-sufficiency stem from an era when undernourishment (in terms of energy intake) was the prime nutrition problem. This has changed in most LMICs. Hence, it is time for national agricultural policy to address new nutritional challenges.

Yet, current agricultural subsidies and other support to farmers have often a social protection objective in addition to the agricultural production objective, as farmers make up a large share of the poor population. Cutting agricultural subsidies may therefore lead to real income losses for farmers, if no compensation mechanism is in place. Moreover, input cost subsidization and output price protection for key food crops (sometimes referred to as 'strategic crops') are often intertwined with government social protection programs such as household food assistance and school feeding programs. Moving from a food-based support system to a cash-based support system may hence help to implement fundamental agricultural policy reforms.

Reforming agricultural policies for improved nutritional outcomes, however, is faced with critical knowledge and data gaps, especially in LMICs. For example, rigorous studies that analyze the dietary and nutritional impacts of specific agricultural policies are scarce and lacking for Africa and the Middle East. Moreover, existing studies that advise agricultural policies on nutrition-sensitivity tend to fall short on examining the costs and benefits associated with the recommendations made. Research is also limited by vast gaps in (publicly) available data. For example, most LMIC governments do not publish (or even document) national expenditure data disaggregated by specific agricultural investments and programs on an annual basis. Global and national horticultural price data for the most important vegetables and fruits are missing, and available production data are usually of poor quality. Narrowing these knowledge and data gaps ought to be a priority of food policy research.

The potential contribution of reshaping agriculture to reduce obesity in LMICs may be more limited than the potential contribution of changing established practices in other sectors of the food system such as in food processing, marketing, retail, and services. Nevertheless, agricultural policy reforms are needed in many LMICs to restore the sector's competitiveness, which provides a unique opportunity to enable the agricultural sector to contribute its share. Research can play an important role to make agriculture more nutrition-sensitive by helping policy makers in evidence-based decision making in reforming outdated and nutritionally adverse agricultural policies.

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A woman examines and sorts iron beans in Rwanda. Nutrition-sensitive agricultural programs, such as biofortification or homestead food production systems, may be well suited for increasing people's consumption of high-quality diets. (Mel Oluoch/HarvestPlus)

9

New Evidence on Nutrition-sensitive Agricultural Programs

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Introduction

Globally, the case for redesigning agriculture to support better nutrition and health is well recognized and was featured in the process that established the United Nations (UN) 2030 Agenda for Sustainable Development (UN, 2017). At the regional level, this shift can be seen in the growing number of initiatives to support national governments in integrating nutrition into their agricultural investment plans, as illustrated by the Comprehensive Africa Agriculture Development Programme investment plans (Rampa and van Seters, 2013). At the national levels, countries like Nigeria and Ethiopia, for example, have recently developed nutrition-sensitive agricultural plans, a clear manifestation of the greater political priority being given to improving the nutritional impact of investments in the agricultural sector.

Making agriculture more nutrition-sensitive (see definition in Box 9.1), however, requires a new way of thinking, planning, implementing, and partnering, as well as the active engagement of a variety of stakeholders from multiple sectors. It also requires identifying critical entry points where nutrition goals and interventions can be incorporated into agro-food systems (Jaenicke and Virchow, 2013). Some of the initial steps undertaken to bring the relevant stakeholders and sectors together include designing and agreeing on conceptual frameworks that identify the multiple pathways by which agriculture can impact nutrition. This topic has been the subject of an extensive body of work including the development of several conceptual frameworks that highlight the dynamic and multifaceted linkages among agriculture, health, and nutrition (World Bank, 2007; IFPRI, 2011; Headey *et al.*, 2012; Pinstrup-Andersen, 2012; Jaenicke and Virchow, 2013; Ruel and Alderman, 2013; Herforth and Harris, 2014; Kadiyala *et al.*, 2014). The characterization of the pathways by which agriculture and nutrition are linked and of the unequivocal mediating role of women's status and empowerment in these linkages has been instrumental in stimulating the development of new initiatives and investments to leverage agriculture to improve nutrition.

But what is the state of the evidence on whether – and how – agricultural development programs actually improve nutrition? This chapter, which draws from Ruel *et al.* (2018), summarizes key findings from recent reviews of evidence of the nutritional impacts of agricultural programs. It focuses on findings from impact evaluations of different types of nutrition-sensitive agricultural programs, including biofortification, homestead food production systems, livestock transfer programs, value chains for nutritious foods, and irrigation programs. The review also includes, where available, information regarding pathways of impacts, mechanisms, and contextual factors that affect where and how agriculture may improve nutrition outcomes. The chapter concludes with a discussion of what the findings imply for the design and implementation of successful nutrition-sensitive agricultural programs, and highlights some key research gaps that need to be addressed in order to further our understanding of how to unleash the potential of agriculture to deliver on nutrition.

Box 9.1. What are nutrition-sensitive agricultural programs? (adapted from Ruel and Alderman, 2013).

Nutrition-sensitive agricultural programs are those that address some of the underlying determinants of child nutrition – adequate income; access to food in sufficient quantity and quality; adequate care-giving resources at the maternal, household and community levels; and access to health services and a safe and hygienic environment – and incorporate specific nutrition goals and interventions.

Summary of Evidence

A number of reviews of evidence on the impacts and pathways of impacts of nutrition-sensitive agricultural programs on nutrition have been published in the past two decades (see, for example, Ruel, 2001; Berti *et al.*, 2004; Randolph *et al.*, 2007; Masset *et al.*, 2012; Webb-Girard *et al.*, 2012; Ruel and Alderman, 2013; Webb and Kennedy, 2014; Fiorella *et al.*, 2016; Pandey *et al.*, 2016; Ruel *et al.*, 2018). Most reviews up to 2016 included variations of the same sets of empirical studies dating from as early as the 1980s and covering a range of agricultural programs. In spite of differences in the sets of studies reviewed and the methods and nutrition indicators used in the empirical studies, the findings from these reviews were surprisingly consistent. Overall, they found evidence that agricultural development programs that promoted production diversity, micronutrient-rich crops (including biofortified crops), dairy, or small animal rearing could improve the production and consumption of targeted commodities, and some evidence that such improvements led to increases in dietary diversity at the household and sometimes the maternal and child level. The reviews reported a few cases, especially with biofortified vitamin A-rich sweet potatoes, in which increased production and consumption led to improvements in vitamin A status and health in young children, but little evidence overall of impacts on child stunting, underweight, or wasting. Very few of the empirical studies looked at impacts on maternal nutritional status and none documented impacts on other nutritionally vulnerable groups such as adolescent girls.

The inclusion of a strong behavior change communication (BCC) intervention to promote optimal diets and child feeding practices, and a focus on improving women's status and empowerment through agriculture, were consistently reported as key to enhancing the potential impacts of agriculture on diets and other nutrition outcomes. Another main conclusion of the reviews was that most studies so far have had serious methodological limitations that may hamper their ability to demonstrate impacts, especially on anthropometric outcomes. The most common weaknesses included poor evaluation designs, inadequate sample sizes, short duration, and the wrong age group targeted and analyzed for achieving and demonstrating impacts on child anthropometry (Masset *et al.*, 2012; Webb-Girard *et al.*, 2012; Ruel and Alderman, 2013; Leroy *et al.*, 2016).

A recent review (Ruel *et al.*, 2018) uncovered 16 new peer-reviewed articles published over a short 3-year span (between 2014 and 2017) that reported findings from impact evaluations of similar types of agricultural development programs as those reviewed earlier, including three on biofortification, eight on homestead food production systems or home gardens, three on livestock, one on a dairy value chain, and one on irrigation. The most consistent finding from this recent review of nutrition-sensitive agricultural programs, which all aimed to increase household access to nutrient-rich foods, was that they indeed had significant impacts on household and child dietary diversity (where studied) and on the consumption of animal-source foods or fruits and vegetables (where targeted). Impacts on micronutrient intakes were also found in studies that measured dietary intake through a 24-hour recall such as the evaluations of vitamin A-rich orange-fleshed sweet potato (OSP) promotion in Mozambique and Uganda (de Brauw *et al.*, 2015). These results were achieved in diverse settings and through a variety of program models including biofortified vitamin A-rich OSP, gender- and nutrition-sensitive homestead food production systems, livestock and dairy value chain programs, and a fruit and vegetable solar market gardens irrigation program. Overall, these programs were highly successful at meeting their production and consumption goals and at increasing access to nutrient-rich foods among poor households and individuals.

The new set of studies reviewed by Ruel *et al.* (2018) also generated evidence of the impacts of homestead food production systems including fruit and vegetable gardens and chicken rearing on child hemoglobin (Hb) and anemia in Burkina Faso (Olney *et al.*, 2015) and Nepal (Osei *et al.*, 2017), where it was assessed. These studies added to previous evidence of impacts on micronutrient status (vitamin A) provided by the evaluation of biofortified vitamin A-rich OSP in Uganda (Hotz *et al.*, 2012). The studies that used a homestead food production system (Osei *et al.*, 2015, in Nepal) or a dairy value chain platform (Le Port *et al.*, 2017, in Senegal) to distribute, respectively, micronutrient-fortified sprinkles and yogurt targeted to young children also documented impacts on anemia and Hb. These studies show that agricultural programs could be effective platforms to deliver micronutrient-fortified products targeted to young children or other household members. Of the six studies that measured child anthropometry (Miller *et al.*, 2014; Rawlins *et al.*, 2014; Olney *et al.*, 2015; Osei *et al.*, 2015, 2017; Kumar *et al.*, 2018), however, none found an impact on stunting, with the exception of the livestock study in Nepal that found impacts in Terai, but not in the Hill regions (Miller *et al.*, 2014). Impacts on wasting, or low weight-for-height (WHZ), were reported in four studies, but were generally of small size or only marginally significant (Miller *et al.*, 2014 in one region only; Rawlins *et al.*, 2014; Olney *et al.*, 2015; Kumar *et al.*, 2018). Three studies documented reductions in diarrhea prevalence or days sick in young children (Miller *et al.*, 2014; Jones and de Brauw, 2015; Olney *et al.*, 2015), and two showed reductions in the prevalence of maternal anemia and underweight (Olney *et al.*, 2016b; Osei *et al.*, 2017).

Overall, the new empirical studies published since 2014 have expanded the breadth of agricultural programs studied (from traditional home gardens to homestead food production systems with small animals, livestock programs, dairy value chains, and irrigation) and the set of nutrition outcomes measured in children (from anthropometry and diets to micronutrient status and morbidity). New studies also started to document some of the untapped potential of agriculture to improve women's nutritional status, especially in countries such as Burkina Faso, Nepal, and Zambia, where maternal undernutrition is a critical problem. The studies also used more consistent indicators of household, women's, or children's dietary diversity, allowing for comparability across contexts. The range of effects on production and consumption varied between studies, but in general, impacts on maternal and child dietary diversity, food intake, micronutrient status, and weight-specific nutritional status indicators were modest. For stunting, the lack of impacts may be explained at least in part by the relatively short duration of most programs (1.0–2.5 years) and the wide age range targeted by many, often well beyond the first 2 years of life, when the greatest benefits on child growth from nutrition interventions can be expected (Black *et al.*, 2013; Leroy *et al.*, 2016). As documented before, some studies also may have been underpowered to detect effects on stunting (Herforth and Ballard, 2016).

Another improvement from previous literature is the fact that several new studies collected rich data to document the impacts of agricultural programs along the project-specific hypothesized pathways, strengthening the plausibility of impacts on maternal and child diets and nutritional status outcomes. For example, results from the evaluation of the Enhanced Homestead Food Production (EHFP) system, which incorporates a stronger nutrition education intervention using social behavior change approaches, among other components, in Burkina Faso and Zambia showed impacts on specific dimensions of women's empowerment such as social capital, ownership of and control over assets, and decision making in selected domains, and a number of studies documented impacts on maternal infant and young child feeding (IYCF) knowledge, practices, or both (Miller *et al.*, 2014; van den Bold *et al.*, 2015; Murty *et al.*, 2016; Kumar *et al.*, 2018). These findings confirm the hypothesized mediating (and in some case modifying) role of women's empowerment and improved knowledge and practices in fostering nutrition impacts from agriculture (SPRING, 2014).

The 2017 review (Ruel *et al.*, 2018) also noted the marked improvements in recent studies both in program design and in the quality and rigor of impact evaluations. In contrast with the studies included in previous reviews, most of the recent agriculture and nutrition programs published since 2014 were truly nutrition sensitive (except for some of the livestock studies and the irrigation study) in that they had both explicit nutrition goals and carefully designed nutrition interventions. Nutrition, health, and water, sanitation, and hygiene (WASH) BCC were the most common nutrition-related interventions provided, but a few studies also delivered micronutrient-fortified products, recognizing that in some contexts increasing household access to nutritious foods may not be sufficient to meet the high micronutrient requirements of children in their first 2 years of life. Several of the programs also had a strong focus on gender equity and women's empowerment, which included not only targeting women but also engaging women, men, and communities through training and social mobilization and carefully designed promotional activities. The purpose of these gender-focused activities was not only to improve the quality and productivity of women's lives but also to ensure that resources would be used more efficiently to support children's nutrition, health, and well-being. Only two studies specifically measured and documented impacts on women's empowerment outcomes (Olney *et al.*, 2016a; Kumar *et al.*, 2018).

In addition to having improved program designs, the new studies have tended to pay more attention than before to implementation quality, and a few of them documented working with researchers to design a program impact pathway framework (Rawat *et al*., 2013) and to measure, through process evaluations, implementation fidelity, quality of service delivery, quality of supervision structures, use of the program by targeted beneficiaries and perceptions and appreciation of the program from implementers and users (Olney *et al*., 2015, 2016a; Osei *et al*., 2017; Nielsen *et al*., 2017). The International Food Policy Research Institute (IFPRI) evaluates nutrition-sensitive programs (including nutrition-sensitive agricultural programs) using a rigorous impact evaluation design, in addition to process evaluations using mixed methods in order to produce evidence on whether or not the programs being evaluated achieve the expected impacts on targeted outcomes, and also to answer the questions of how and why impacts are achieved (for detailed descriptions of the approach, see Menon *et al*., 2013; Rawat *et al*., 2013; Olney *et al*., 2017; Leroy *et al*., 2016). The experience of the partnership between Helen Keller International (HKI) and IFPRI in working together over several years on evaluation and learning around a homestead food production system program implemented in Burkina Faso is described in Nielsen *et al*. (2017).

Overall, the quality of impact evaluation designs and analyses improved in the newly published studies, with more studies using cluster randomized controlled trials or quasi-experimental approaches. More studies than before used baseline and endline surveys and valid comparison groups (through either randomization or matching) to document impacts, but weaknesses remained in some studies, including the lack of a valid control group or of baseline information.

Implications of Evaluation Findings for Program Design, Targeting and Implementation

Evidence from the new body of research now available on nutrition-sensitive agricultural programs has direct implications for their targeting, design, and implementation, which are summarized below.

Nutrition-sensitive agricultural programs can improve a variety of nutrition outcomes in both mothers and children, especially when they include nutrition BCC and carefully designed interventions to empower women, including interpersonal counseling and social mobilization. Greater benefits for child nutrition outcomes (for example, dietary diversity, nutrient intakes, Hb/anemia, diarrhea, and wasting/WHZ) are achieved when programs also incorporate actions to improve health seeking and WASH practices and provide specially formulated fortified products to address children's (and/or pregnant and lactating mothers') high nutrient requirements in areas where access to nutrient-rich foods is limited. Thus, the minimum package of nutrition interventions that should be added to agricultural programs to maximize their impact on nutrition includes a strong and well implemented BCC strategy, culturally sensitive women's empowerment activities, and the provision of micronutrient-fortified products for nutritionally vulnerable household members, especially in areas where access to animal-source foods and fortified products is limited.

With the recent focus on the first 1000 days of childhood as the critical period to intervene in nutrition and the call for action on reducing stunting, many agricultural development programs switched from an earlier focus on improving household production, food security, and dietary quality to a goal of reducing child stunting. As a result, several programs shifted their targeting mechanism from the community level (based on poverty and food insecurity) to poor households with pregnant women and children in their first 1000 days. This shift is appropriate if the main nutrition goal of the program is to reduce stunting, but current evidence suggests that agriculture may in fact be more beneficial for improving household access to nutritious food and diverse diets than for reducing stunting, and for household members other than young children, who have particularly high nutrient needs. While ongoing research will continue to generate information on best approaches to targeting of nutrition-sensitive agricultural programs, our assessment of current literature brings us to recommend that agriculture should target households and focus on supporting access to and consumption of high-quality diets rather than on directly reducing childhood stunting. Improving diets for all household members is a much more logical, reasonable, and achievable goal for agriculture than addressing childhood stunting, and is equally important for global development (GPAFSN, 2016; Herforth and Ballard, 2016). Reviews show that nutrition-sensitive agricultural programs consistently improve household access to nutritious foods and the quality of mothers' and young children's diets. Although this has not yet been tested, it is likely that these programs can convey similar benefits to other household members, including the nutritionally vulnerable adolescents and elderly. The main implication of this recommendation for nutrition-sensitive agricultural programs is that they should continue to be designed carefully, taking into account the specific context in which they are to be implemented, and using formative research to identify the main constraints that limit household and individual access to healthy diets, women's empowerment, and optimal nutrition.

A main take-away from the Ruel *et al.* (2018) review is the importance of context in determining how, to what extent, and under what conditions agricultural programs impact nutrition. One of the key contextual factors found to modify or mediate the impacts of agricultural interventions on nutrition was market functionality and access. Promoting production diversity was found to be much more important for ensuring household access to diverse diets in areas where households had limited access to markets (and were unable to sell and purchase products) than in areas where farmers had greater access to markets (Sibhatu *et al.*, 2015). This finding has clear implications for continued work on market development, which in and of itself would likely improve diets among poor households living in remote areas. Another implication is that markets could be leveraged to become more nutrition sensitive and provide a source of information about nutrient-rich foods, healthy diets, and meal planning, further impacting diets and nutrition. This approach, which has been proposed to study traditional value chains (Hawkes and Ruel, 2011; see also Chapter 3, this volume), would need to identify and involve all market actors and institutions to work toward the common goal of improving access to, affordability of, information about, and demand for nutritious and diverse diets. Several other contextual factors, including women's social status and empowerment; social norms; and socioeconomic, environmental, political, cultural, and food environment factors, were identified as key aspects that affect the uptake of, response to, and nutrition impacts of agriculture programs (Fiorella *et al.*, 2016; Herforth and Ballard, 2016). The importance of context needs to be addressed, and it is possible that some typologies of contexts and related decision-making tools could be designed in the future when results from a larger body of evidence are available.

Key Research Priorities

To further enhance our understanding of the value and contribution of household- and community-focused agricultural programs to women's empowerment and to maternal, adolescent, and child nutrition, we provide examples of some priority research areas.

Long-term impacts and sustainability

So far, no information exists on the long-term impacts – or the sustainability of any impacts – of nutrition- and gender-sensitive programs, nor on the sustainability beyond these programs' specific funding cycles of the practices adopted or assets built by participants. Research on the long-term impacts and sustainability of impacts and implementation of nutrition- and gender-sensitive agricultural programs should be prioritized.

Scaling up and operating at scale

Data, information, and evidence from efforts to scale up nutrition-sensitive agricultural programs are extremely slim (Linn, 2012; Gillespie *et al.*, 2015). Research is needed on how and where to scale up or implement such programs at scale, what are the key factors for success, and what is the cost of scaling up and achieving impacts at scale. Research should also characterize how agricultural development programs can fit within – and complement – the scale-up of larger agricultural and food systems investments.

Cost and cost-effectiveness

Cost-effectiveness assessments, which focus on one outcome (for example, stunting), cannot capture the multiple benefits of programs that generate impacts on a series of outcomes (for example, women's empowerment, knowledge, diets, nutritional status) (DFID and BMGF, 2017). Cost-effectiveness assessments of such programs also cannot factor in the benefits that the programs may have on several of the underlying determinants of stunting, which in turn may have long-term cumulative impacts on either the targeted children, their younger siblings, or the next generation. Cross-disciplinary research is urgently needed to develop methodologies to assess cost-effectiveness for programs that are designed to have impacts on a suite of outcomes.

Which target groups, which nutrition outcomes?

Research should continue to assess which nutrition indicators (for example, diets or micronutrient intake and status) are most likely to respond to agriculture interventions, and which household members are most likely to benefit. Research should be undertaken to redefine which nutrition outcomes and which age groups agriculture should aim to support in different contexts. Research should also focus on improving the quality of, while also simplifying, data collection and processing for dietary assessment, and more specifically for assessment of the quality of diets in different population groups.

BCC in the context of agricultural programs

Process evaluations of agricultural programs have identified BCC as a common bottleneck in implementation (Olney *et al.*, 2009, 2016b), and although most programs have shown some impacts on knowledge and practices, there is room for much more improvement than what is usually achieved. Research is needed to identify best practices in designing and implementing effective yet affordable BCC strategies in the context of agricultural programs and how to make them attractive and useful for beneficiaries without adding too much burden on their time. BCC topics also need to be broadened, from the traditional focus on optimal IYCF practices to the promotion of healthy and nutritious diets, meal planning and budgeting, WASH, and health service utilization for all household members.

Integration or co-location

Converting agricultural development programs into multisectoral, nutrition-sensitive programs requires incorporating a series of nutrition interventions that may greatly increase the complexity and potential overload of the programs. This raises the question of whether real 'integration' is necessary, or whether 'co-location' could be as effective (Ruel and Alderman, 2013). This question relates to whether it is necessary to integrate multiple interventions from different sectors into programs, at the risk of making them overly complex and difficult to implement and scale up with quality, or whether the same impacts could be achieved by co-locating or targeting sectoral interventions to the same individuals, households, or communities. A recommendation to 'think multisectorally, and act sectorally' (World Bank, 2013) suggests stimulating dialogue across sectors at the planning, monitoring, and review stages, while ensuring that each sector uses its unique expertise to implement (sectorally) with quality and efficiency. This approach should be rigorously tested and compared with integrated programs offering the same set of interventions, using implementation and impact research tools to assess efficiency, effectiveness, and cost-effectiveness.

Context, food environment, and gender roles

The importance of broad contextual and food environment factors in shaping the agriculture and nutrition equation is clear. There are useful frameworks to characterize – and indicators to measure – food environments (GPAFSN, 2016; National Cancer Institute, 2017), and researchers need to use them and if possible create typologies of food environment contexts that would require or could accommodate different types of nutrition-sensitive agricultural interventions. Similarly, gender roles are culture and context specific, and research could be undertaken to create typologies of how gender roles interact with nutrition-sensitive agricultural interventions.

The role of markets and nutrition-sensitive market interventions

The findings also showed that market access was a consistent and large modifying effect of the impacts of agriculture on nutrition outcomes, especially access to and consumption of diverse diets. Research on how different types of markets can support improvements in diets and nutrition is needed. Research is also needed to test effective interventions to support increased production diversity and nutrition knowledge (through targeted BCC) in communities where access to markets continues to be limited.

Unintended negative impacts of agriculture programs on nutrition

The two main types of potentially negative consequences of agriculture include impacts on women's time for child feeding and care, and the health and nutrition risks associated with exposure to livestock and chicken feces, especially for young children. More research is needed to document the importance, nature, and consequences of these risks, and to design and test effective measures to mitigate them.

Conclusions

The past decade has seen a lot of enthusiasm, interest, and investments in leveraging agriculture to improve nutrition. Research on the topic has increased exponentially, and so has the quality of the evidence. Guidance on how to improve the nutrition sensitivity of agricultural programs is also widely available and implementation capacity stronger. A number of key research gaps still need to be filled, however, in order to successfully replicate, adapt, scale up, and mainstream nutrition-sensitive agriculture and achieve sustainability of implementation and impacts. With the rich set of ongoing studies, a greater understanding of what agriculture can and cannot do to contribute to nutrition improvements, and a solid commitment to achieving the UN's Sustainable Development Goals, the next 10 years promise to bring new evidence, action, and successes in improving nutrition through agriculture.

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A man affected by drought in Kenya receives a cash transfer, enabling him to purchase a goat. Cash transfers often allow beneficiaries to build up assets that could lead to good nutrition and health. (Aidan O'Neill)

10

Safety Nets for Agriculture and Nutrition

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Introduction

Safety nets – including conditional and unconditional cash and in-kind transfers, school meals, public works, social pensions, and targeted subsidies – are a leading strategy for governments and their partners to reduce poverty and inequality. Many safety net or social protection programs provide monthly or quarterly payments of cash, food rations, or other in-kind transfers targeted to poor households, sometimes under the requirement that households meet certain 'conditions', including minimum school attendance for school-age children, completing health checkups for children under the age of 3, or meeting work or training requirements such as on public works projects.

A primary objective of safety net programs is to transfer resources through government fiscal policy or from international humanitarian aid sources to poor households in order to reduce poverty and inequality. Although safety nets sometimes aim to place a floor on the level of wellbeing below which no household should fall, in practice the size of safety-net transfers rarely varies according to the severity of a household's poverty (other than increasing by household size). Thus, safety net programs can be better understood as providing an income transfer that moves a targeted household from the lower tail of the income distribution up to a somewhat higher level. Safety net programs also often include objectives and program designs to address sources of poverty by fostering investment in agriculture or other sectors that provide an income; or investments in the human capital of children through education and nutrition, in order to reduce the intergenerational transmission of poverty.

The past two decades have seen massive expansion of safety nets to address poverty and its manifestations in education, health, employment, and income growth in low- and middle-income settings. The World Bank reports that 99 countries currently provide unconditional cash transfers; 61 provide conditional cash transfers; 114 provide school meals; and 95 provide some form of public works (World Bank, 2018). Far fewer countries had significant programs in the early 2000s. Estimates vary, but indicate a consistent pattern of growth in safety net programs with the number of people receiving cash transfers or vouchers growing from 1–1.5 billion in 2013–2014 (Fiszbein *et al.*, 2014; ODI and CGD, 2015) to 2.8 billion in 2016 (CaLP, 2018).

Based on evidence of the success of early conditional cash transfer programs in Latin America and the Caribbean (LAC) in the 2000s (Fiszbein and Schady, 2009), governments and their partners in sub-Saharan Africa (SSA), South Asia, and East Asia and the Pacific (EAP) began experimenting with pilot programs and, in many cases, developed national safety nets. For example, national transfer programs were started between 2005 and 2008 in Ethiopia, Ghana, Indonesia, the Philippines, and Tanzania and in a second wave from 2014 to 2015 in Egypt, Mali, and Senegal. With this growth in safety nets, program modalities and objectives became more diverse as designs were tailored to the local context. In SSA, for example, it is less common for cash transfers to be conditioned on primary school attendance than in Latin America. One reason is that the need for broad improvements in school participation in SSA made free universal primary education a more effective policy for this objective. In addition, SSA and South Asia face much higher rates of malnutrition than Latin America. As spending on social protection grew, reaching 1.5% of gross domestic product (GDP) in SSA in 2015 (World Bank, 2018), governments and their partners wanted to see impacts on malnutrition from their massive investment in social protection for the poor. Therefore, national social protection programs in Ethiopia, Mali and elsewhere in SSA now have explicit nutrition objectives.

Recent efforts by governments, donors, implementation partners and the research community have emphasized the potential to improve the nutrition impact of agriculture, making value chains more nutrition sensitive. The promise of these initiatives could be enhanced by harnessing the resources provided by cash or food transfer schemes and the safety net delivery systems. However, designing effective programs with safety net, agriculture, and nutrition components raises challenges for coordinating service delivery across these sectors in order to determine how transfers and agriculture will work together to improve nutrition. This chapter explores the potential for such a partnership. It presents selected evidence on the impact of safety nets on agriculture and nutrition separately, examines trends in the development of more integrated programs, and outlines key areas of potential and challenges to better harnessing safety nets for agriculture and nutrition.

Social Protection and Agriculture

One significant development in safety net modalities during the past decade has been the broader inclusion of asset transfers and other co-investments to strengthen the impact of safety net programs on income growth, often through agriculture. This shift was a result in part of two effects of growing budgets for safety net programs. First, as governments gained experience with the cost of running large safety net programs over many years, they saw that graduation was a problem. On average, safety net programs cover only one out of every five poor households (Alderman *et al.*, 2018). The resulting pressure to enroll more poor households in the programs leads to demand from policymakers to remove those households whose incomes have grown sufficiently that they no longer qualify for the transfers – a measure of graduation. In practice, cash transfer programs keep households from falling further into poverty, but less frequently lead to sustained income growth and poverty alleviation for large numbers of beneficiaries. Second, budgets for safety net programs now outstrip budgets for agriculture in many countries (Alderman, 2016). This development has placed pressure on safety net programs to adopt some of the policy objectives of shrinking agricultural spending and to coordinate transfers with complementary agricultural information and technology programming to support agricultural development.

Efforts to improve the impact of social protection programs on agricultural development by adding complementary agricultural information or technology are relatively few and face challenges. First, the poorest beneficiaries of targeted safety net programs may be less productive in agriculture because they face multiple constraints in markets for land, financing, or inputs (Sadoulet *et al.*, 2001; Jack, 2013). Low adoption of agricultural technologies can also be explained in part by heterogeneity in the cost of obtaining those technologies (Suri, 2011), which may generally be higher for poor, remote households. Poor households also cannot afford the risk of failure in adopting a new technology, a result of missing insurance markets (Feder *et al.*, 2009; Bryan *et al.*, 2014). These concerns may suggest a typology in which social protection is used as the residual intervention for poor households that cannot otherwise benefit from agricultural extension, training and investment, and that public investment in agriculture is reserved for better-off farmers. Such a conclusion would be too simplistic. Combining targeted income transfers with access to agricultural technology and training may have substantial potential to overcome constraints in access to quality inputs, financing, and information.

Evidence on the impact of social protection programs on agriculture has grown substantially, providing lessons on the conditions for social protection to improve agricultural development and identifying promising modalities requiring further study. On their own, social protection programs providing regular transfers reduce poverty (Fiszbein *et al.*, 2014) and contribute to asset formation in the form of livestock, farm and non-farm productive assets and savings (Hidrobo *et al.*, 2018a). These patterns of transfers contributing to growth in agricultural assets are encouraging, but there is very little evidence that these assets contribute to further agricultural intensification and income growth that leads to large-scale, sustainable income growth and poverty reduction.

The potential for safety nets to contribute to broader agricultural investment and rural income growth depends on the context, including relevant local constraints to agricultural growth and investment and how the social protection program is integrated with complementary agricultural components to address these constraints. One approach to linking social protection transfers to local agricultural development includes public works or productive safety net programs, in which beneficiaries supply work on community projects in exchange for access to transfers. Prominent examples of large national programs include the National Rural Employment Guarantee Act (NREGA) in India and the Productive Safety Net Programme (PSNP) in Ethiopia (see Chapter 16). The labor teams assembled through these programs often build local infrastructure such as roads or dams or implement soil and water conservation projects that may support agricultural development. However, there is very little rigorous evidence on the returns to these public goods for the productivity of local agriculture; the anecdotal evidence is mixed (del Ninno *et al.*, 2009). Some effects of the labor requirement from these programs are better understood. The work activities are usually implemented during the slack period for agricultural labor and offer a wage rate and labor hours that avoid crowding out of private labor supply (FAO, 2015). In the NREGA scheme, where the wage provided is at or above private-sector wages and the program is open to all, evidence shows that the program has increased wages in the private labor market leading to massive spillover effects with larger welfare gains for workers outside the program than in the program (Imbert and Papp, 2015; Muralidharan *et al.*, 2018). The availability of crèches to care for infants made it possible for more women to participate in the program (Alderman, 2016). The program also led to increased land ownership for NREGA participants. Higher incomes led to increased productive assets and livestock ownership and reduced credit constraints for participants and non-participants (Muralidharan *et al.*, 2018).

Ethiopia's PSNP provides an example of a hybrid program that offers selected households a combination of transfers earned through public works and a package of agricultural support including credit, agricultural extension service, technology transfer, and soil and water harvesting schemes. These agricultural investment packages were previously offered through the Other Food Security Program or Household Asset Building Program and are currently provided through the Livelihoods Program in the PSNP. An early evaluation of the combined program from 2006 to 2008 found that it increased the probability that beneficiaries use agricultural credit, use improved seeds, and operate their own non-farm business activities (Gilligan *et al.*, 2009). Follow-up studies further into the program found that households in the joint program with high earnings from the PSNP had significantly higher use of fertilizer and investments in land, water harvesting, and productive assets (Hoddinott *et al.*, 2012), and larger livestock holdings (Berhane *et al.*, 2014).

Evidence on the impact of transfers combined with other agricultural interventions such as input subsidies, micro-credit or agricultural extension is relatively limited, but results suggest promising areas for additional research. For example, Duflo *et al.* (2011) found that discounts on the cost of future fertilizer delivery for the next season offered during the current harvest period had substantial effects on fertilizer use next season and were more welfare-improving and cost-effective than large fertilizer subsidies. It would be useful to test whether combining this 'nudge' intervention with targeted transfers to poor households to improve their access to complementary inputs such as hybrid seed or herbicide would increase impacts or expand take-up of the approach by poor farmers.

We can also learn from evidence on how differences in transfer modalities may also shape impacts on agriculture. Haushofer and Shapiro (2016) experimented with alternative modalities for unconditional cash transfers through Give Directly, an organization that gives cash donations directly to the ultra-poor, and found that monthly transfers have larger impacts on food security while lump-sum transfers have larger impacts on durables, suggesting evidence of credit constraints and a trade-off between current and future consumption. In a follow-up study, these differences in impacts by transfer modality dissipated, and most impacts were not sustained with the exception of a large effect on asset holdings (Haushofer and Shapiro, 2018). Transfer programs that promote agricultural development face a similar trade-off in modalities.

One response to the demand for more sustained income growth from social protection programs has been growth in graduation model social protection programs, like those implemented by BRAC (the international non-governmental development association based in Dhaka and originally known as Bangladesh Rehabilitation Assistance Committee, later Building Resources Across Communities), which include multifaceted program components including transfers, assets, and trainings. Experiments with the BRAC graduation model across six countries found impacts on consumption, food security and productive asset holdings, but also increased agricultural income, livestock revenue and time spent working in agriculture and livestock (Banerjee *et al.*, 2015). The BRAC graduation model programs, however, were expensive, equivalent to 100% of the value of consumption on average, whereas many transfer programs provide between 15% and 20% of consumption. It is challenging to measure cost-effectiveness of a program with such a wide array of outcomes. The case for the cost-effectiveness of these 'big push' programs will be strengthened if further evidence shows that they put beneficiaries on a sustainable path to higher income and higher status across outcomes.

More evidence is needed on improved designs and impact of social protection programs with focused agricultural objectives in which transfers are combined with technologies to promote income growth. Successful programs may be more cost effective than graduation models, but a persistent challenge will be to identify agricultural technologies with the potential to sustain income growth when combined with transfers targeted to the poor. Other models for including agriculture components in social protection come from the UN agencies that provide development assistance. Because of the cost burden of carrying large caseloads under a humanitarian development program, for example, the Food and Agriculture Organization (FAO) of the UN has designed the 'From Protection to Promotion' project to focus the attention of all involved on the need to stimulate growth in beneficiary incomes and room for graduation. Also, the World Food Programme operates the Purchase for Progress intervention, which includes agricultural technology transfers in addition to cash or food transfers, in support of government social protection programs.

Social Protection and Nutrition

Social protection can improve nutrition through three pathways: (i) increased income; (ii) subsidies and price supports; and (iii) changes in preferences and behaviors (Alderman, 2016). Recent reviews present the evidence for social protection to improve diets and nutrition outcomes. Hidrobo *et al.* (2018a) summarized the impact of income from social protection programs on diets in a meta-analysis of 46 social protection programs in 25 countries across SSA, LAC, and EAP. Results showed that the programs, with transfers equal to roughly 18% of the value of baseline consumption, improved household food security, increasing the value of food consumed by 13%, and calories consumed by 8%, while boosting consumption of animal-source foods. Impacts were generally larger in SSA than in EAP or LAC.

Other evidence shows that payment modalities influence program impact on diets but often in unexpected ways, with cash transfers generally doing better than food rations at improving diet quality (Hidrobo *et al.*, 2014; Gilligan and Roy, 2016; Alderman *et al.*, 2018). Experiments to test the relative impact of cash transfers, food rations, and food vouchers across four countries indicate that, even in areas with relatively thin food markets, cash transfers or vouchers perform at least as well as food transfers for improving food security. A multi-country randomized study for the World Food Programme compared cash and food transfer modalities in Ecuador, Niger, Uganda, and Yemen. Results from Ecuador (which included food vouchers) found that all three modalities increased food consumption, with food transfers leading to larger increases in calories consumed and food vouchers leading to larger increases in dietary diversity (Hidrobo *et al.*, 2014). Cash transfers also improved dietary diversity relative to food transfers in Uganda (Gilligan and Roy, 2016). This pattern differed only in Niger (Hoddinott *et al.*, 2018), where providing food rations led to greater dietary diversity than cash transfers. A related study provided further support for cash transfers, concluding that cash assistance was 13–23% less costly to deliver than food rations (Margolies and Hoddinott, 2015).

Despite these improvements in diets, targeted cash transfers or food rations have not been shown to consistently improve the nutritional status of children and adult women. One meta-analysis calculated the impact of cash transfer program on child height-for-age z-scores (HAZ) using data from 21 research papers and 17 projects. The analysis concluded that the estimated average impact of transfers on HAZ was positive, but small and not statistically significant (Manley *et al.*, 2013). A review of programs in Latin America showed uneven impacts on child anthropometry (only for some subgroups) and weak impacts on micronutrient status (Leroy *et al.*, 2009). This failure stems from the fact that modest income growth alone is not sufficient to address the multisectoral constraints to improved nutrition, including knowledge and behaviors around breastfeeding and complementary feeding, sanitation and hygiene, and exposure to infection. One example with more favorable impacts found that conditional cash transfers in the Philippines reduced severe stunting (Kandpal *et al.*, 2016).

Conditional cash transfer programs commonly include conditionalities around clinic visits and vaccinations supported by larger transfers to address objectives related to child health, but until recently few safety net programs included explicit nutrition objectives. A possible exception is school feeding programs, though conventional school feeding programs may not include explicit nutrition objectives but may focus on schooling outcomes alone. Designing social protection programs to improve nutrition often requires improved targeting to households with young children, using conditions to increase the use of healthcare, strengthening the program's nutrition objectives, and including features to improve women's nutrition knowledge, time use, and empowerment (Ruel *et al.*, 2013). It is not practical to condition transfers on child nutrition outcomes like weight gain, as this may create perverse incentives to restrict child growth in order to maintain access to the transfers. Instead, safety net programs with nutrition objectives can condition the transfer on activities that contribute to improved nutrition, like prenatal care visits and child health checkups and vaccinations. However, if the quality of local health services is low, the benefits of such a conditionality may not exceed the cost to the household to fulfill it. Other approaches condition transfers on a related outcome. A recent study (Buchmann *et al.*, 2017), for example, showed that paying incentives to young women to delay marriage in Bangladesh led to a significant 16 percentage-point decline in the probability of giving birth before 20. This likely improves nutrition, as early childbearing is associated with poorer nutrition outcomes.

During the past 10 years, several countries have begun to incorporate explicit nutrition objectives and nutrition programming into their national safety nets. In Mali, for example, the national safety net program Jijisemejiri has included targeted nutrition interventions since 2016 (Hidrobo *et al.*, 2018b). For various reasons, initiation of the nutrition components was delayed for more than 1 year as the government prepared to implement the new nutrition component. Bangladesh has a large number of safety net programs and also operates pilot programs for learning purposes. One example is the Transfer Modality Research Initiative (TMRI) in Bangladesh, a research project that undertook a randomized controlled trial to compare cash and food transfers with and without nutrition behavior change communication (BCC) trainings. Results of an impact evaluation of TMRI found that only the cash+BCC treatment arm improved nutritional status, leading to a sharp decline in stunting prevalence (Roy *et al.*, 2015).

Integrated Agriculture–Nutrition Safety Net Programs

Few social protection programs include additional complementary components in both agriculture and nutrition. The graduation model social protection programs with the strongest evidence combine cash transfers with investments in agriculture but do not also include substantial nutrition components. The experiments with the BRAC graduation model included some level of training in health, nutrition and hygiene, but impacts on child nutritional status were not reported (Banerjee *et al.*, 2015). In addition, popular nutrition-sensitive agriculture programs like homestead gardens, and programs to promote crop diversification for consumption are not often combined with targeted transfers for the poor. Homegrown school feeding programs, however, source their food locally, with the objective of improving the nutrition of school children while also supporting local agriculture. It is harder to fortify locally sourced school meals with additional nutrients, a process that is usually done centrally when fortification is a priority.

One prominent example of the integration of agriculture and nutrition into social protection has been the PSNP in Ethiopia. The government of Ethiopia recently added improved maternal and child nutritional status as goals of the PSNP after more than 10 years of its operation. It also changed the design of the program to help achieve these nutrition objectives, including: (i) automatically transferring a female beneficiary of the public works component of the PSNP to temporary direct support payments for a period of 12 months if she becomes pregnant; and (ii) allowing work requirements to be partly fulfilled for mothers with young children by attending regular nutrition BCC training. Programs combining transfers with agricultural investment and BCC training in nutrition should account for the local context and availability of food markets to determine the optimal transfer modality and whether an agriculture-led strategy to promoting nutrition gains would be effective.

Lessons

Evidence from the existing literature and recent experience of social protection programs with added agriculture or nutrition objectives leads to several lessons about how to better design programs for the blended objectives of maintaining consumption and food security in the short run, increasing agricultural development and income, and improving maternal and child nutrition outcomes.

1. The best design for a national social protection program depends on policy priorities. If the policy objective is to extend the progress in improving household food security and schooling already realized and further build human capital by improving child nutrition through the program, existing evidence identifies some promising strategies and programming modalities to improve the nutrition impacts of social protection programs. These include effective targeting of the programs to at-risk pregnant women and households with young children, on-time delivery of regular transfers and complementary BCC and nutrition interventions. There is much more to learn on these types of program designs, but many promising studies are under way. Alternatively, if the policy priority is on agricultural development and increasing incomes for the (rural) poor, then more work is needed to find an analogous approach to twinning transfers with information and technology to improve agriculture outcomes, as has been done for nutrition. Here similarly, there is much more work to do, in part because the strategies needed to boost agricultural development are far more diverse and contextually based than for nutrition.

2. Designing national social protection systems for agriculture and nutrition involves several complications. First, ministries of social welfare, agriculture and health are often not accustomed to working together. Effort will be needed to support coordination in implementation across the ministries. Neither agriculture nor safety net transfers alone will eliminate stunting, so coordination is needed. The primary benefit of a more coordinated approach involving social protection plus agriculture and nutrition is sustainability: programs that provide short-term transfers, add access to quality agricultural technologies, improve the hygiene and sanitation environment, and provide support for optimal child feeding and caring practices are likely to have much more sustainable impacts.

3. Integrated safety net programs must address several other challenges to be effective and sustainable:

- Competition in funding: limited budgets will lead to competition across ministries for funding. Ministries will need to coordinate their service delivery to be cost-effective and avoid duplication of costs. It may be necessary to retrain front-line service providers so that health workers can integrate agricultural tips into their messages on child feeding practices and agriculture extension agents can better understand basic nutrition, for example.
- Targeting: one of the most challenging issues for an integrated social protection, agriculture, and nutrition program will be to decide how to target the program. Targeting to very asset-poor households may weaken the impacts on agricultural growth yet be effective at poverty reduction. Similarly, transfers need to be designed to reach pregnant women and women with young children. This consideration often means providing transfers directly to women, but that approach may interfere with the objective to use part of the transfer to invest in agriculture if men are not included.
- Designing programs for urban areas: agriculture will be a less prominent component of the program in urban areas as beneficiaries must obtain most of their food from the market. Variation in types of foods available and exposure to poor sanitation and hygiene environments will also need to be factored into designs.
- Layering interventions in transfers, nutrition, and agriculture could become very expensive. It will be necessary to find and test

narrow interventions that might make the overall approach more cost-effective.

4. Broad and sustainable improvements in the impacts of social protection on child nutrition, on women's status, and potentially on inequality require designing programs to be better at improving outcomes related to underlying rights, gender norms, and local institutions. The results of the BRAC graduation experiments showed an impressive breadth of impacts on consumption, incomes and savings, but no effects on women's roles in decision making. Nutrition impacts are likely to be limited over time without making improvements in women's control over resources in the home. Hidrobo *et al.* (2016) found that transfers from social protection programs provided to women increased their control over decision making and reduced the incidence of intimate-partner violence. These impacts likely reflect thought that went into designs for these outcomes, such as targeting transfers to women. But there is likely substantial room to increase these impacts through additional complementary interventions. For example, more equitable access to land for women in poor households may boost agricultural productivity by reducing the inefficiencies documented from a gender-based inequity in distribution of land and cattle (Hoel *et al.*, 2017).

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An advertisement for baby formula in Hong Kong. Many large companies have violated the International Code on the Marketing of Breastmilk Substitutes, causing distrust on their role in nutrition. (IQ Remix/Flickr)

11

How Can Businesses Operating in the Food System Accelerate Improvements in Nutrition?

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Introduction

Poor diet is the common currency of all forms of malnutrition (GBD 2016 Risk Factors Collaborators, 2017). Diets that are deficient in key nutrients such as vitamin A, iron, and zinc or laden with unhealthy diet components such as salt, added sugar, and trans fats will prevent optimal child growth and development, make it more likely that women will have high levels of anemia, and promote obesity, type 2 diabetes, and hypertension (IFPRI, 2016).

Food systems – everything from what is grown to what is eaten – play a key role in determining the availability, affordability, and desirability of nutritious foods. Food and agricultural

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systems currently meet the food and nutrition needs of approximately two out of three people (IFPRI, 2016). That leaves between 2–3 billion people around the world who are not well served by the status quo. What can be done to make these systems more nutrition promoting?

Governments set the rules of the game for food systems (GPASFN, 2016; HLPE, 2017). They can create positive incentives for businesses to do better things for nutrition and negative incentives for them to do harmful things. Businesses – small, medium, and large – are the key investors in the system and, within the imperative to maximize profit, can do things that are more or less positive for nutrition outcomes. Another set of core actors in the global food system is civil society. This group has the power to support elected representatives who set and enforce rules and also to name and fame businesses and governments according to their commitment and performance in advancing nutrition according to those rules.

This chapter outlines some of the actions that businesses can take to improve nutrition outcomes and what governments and civil society can do to incentivize them to do so. The chapter argues that a failure to incentivize businesses to do more to improve nutrition results in missed opportunities to meet the UN Sustainable Development Goal target of ending malnutrition by 2030.

Why Businesses Matter for Nutrition Outcomes

As the world urbanizes and markets grow, more and more people will access their food from businesses via the market (GPASFN, 2016). The latest data from the World Bank (Fig. 11.1) indicates that most households, even in the lowest-income countries, access food from markets rather than home production. As indicated in Fig. 11.1, in India in 2011 over 80% of the food acquired by households was purchased from markets. Even for the country with the lowest share of food acquired through markets, Mozambique (in 2008), it was over 40%.

The spatial and temporal distance between what is grown and what is consumed is likely to grow, increasing the opportunities for nutrients to leave the food value chain – but also increasing the opportunities for nutrients to enter the food value chain (Fig. 11.2). Even though agriculture's share of activities within value chains will diminish as food products become more processed, agricultural input and output markets will remain a vital first step in setting a nutrition trajectory for a food product. For example, biofortification of beans can, if effectively commercialized, transform the nutrient delivery of an entire value chain, helping to get fortified bean flour into a variety of food products, such as noodles.

How to Incentivize Businesses to Advance Nutrition Outcomes

So what can be done to get businesses within food systems to do more to improve nutrition status? There are three sets of actions with key roles for each of the sets of stakeholders: (i) creating demand for nutritious foods; (ii) improving the supply and affordability of nutritious foods; and (iii) creating an enabling environment for businesses to improve nutrition.

Creating demand for nutritious foods

The first set of actions is around demand creation (Table 11.1), more specifically building demand through compelling public behavior-change campaigns and shaping demand through price policies.

Businesses often claim that if there were a bigger demand, they would produce more healthy foods. The private sector certainly shapes demand for its own products, but it is perhaps too much to expect it to generate the demand for nutritious food as a whole. This is the job of governments. Yet public nutrition behavior-change campaigns tend to restrict their focus to evidence and cause and effect without appealing to consumers' emotions. The private sector is very good at generating demand for products that are much less essential than affordable nutritious food. We need more blended public nutrition messaging that retains a strict fidelity to government guidelines on nutrition but uses aspiration, emotion, and creativity to make messages engaging, compelling, and 'sticky'. For example, in 2014, the Indonesian government collaborated with the Global Alliance for Improved Nutrition (GAIN),

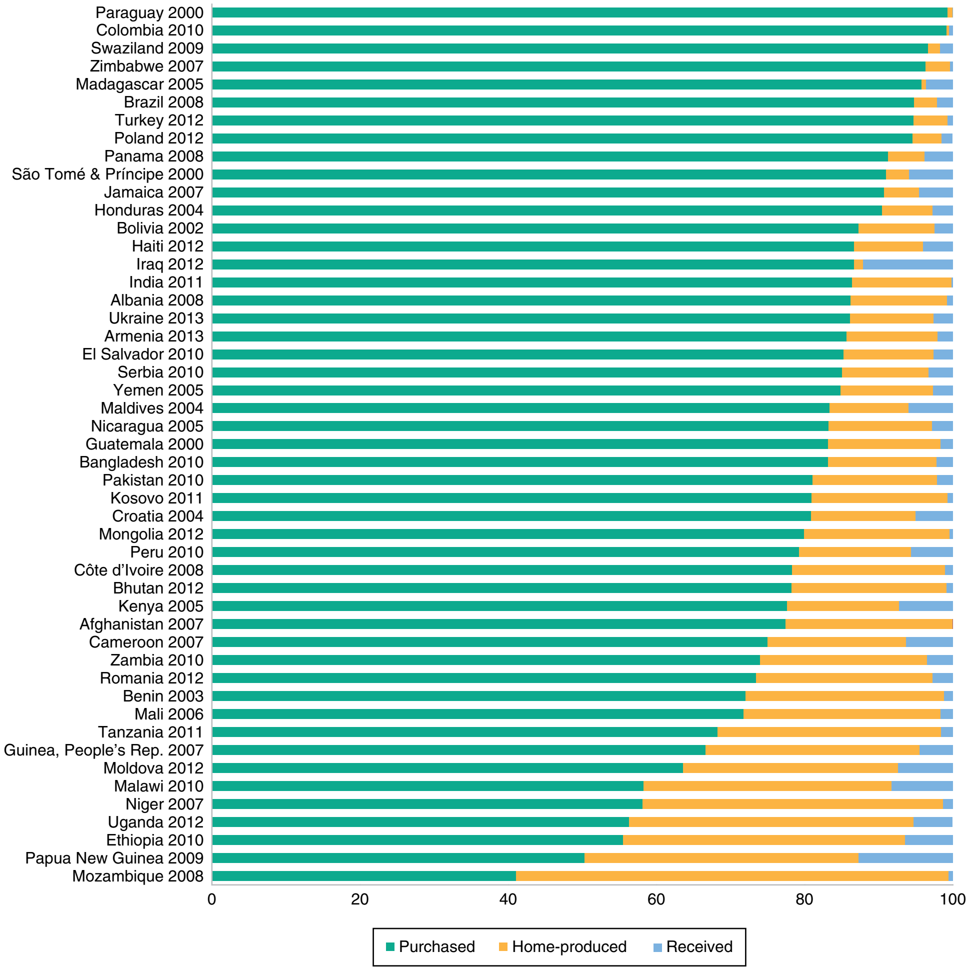

Fig. 11.1. Household value of food consumed: percentage by source of acquisition (data compiled by World Bank LSMS team; Global Panel on Agriculture and Food Systems for Nutrition, 2016).

the London School of Hygiene and Tropical Medicine, and a local advertising agency on crafting nutrition messaging. The result was the 'Healthy Gossip' campaign, a 1-minute video during which a mother gossips about how everyone else is failing to feed their children properly. The use of humor and emotion within the video seemed to work, in contrast to standard government-produced instructions about what people should be eating. An independent evaluation of the program involving the campaign indicated that it helped 50% of the 6–24-month-old infants in the villages assessed to meet a 'nutrient adequacy threshold', compared with 36% of infants in the control villages (University of Sydney, 2017).

Demand is also shaped by price signals. Nutritious foods are relatively expensive in most countries (Biehl *et al.*, 2016; Miller *et al.*, 2016; Bachewe *et al.*, 2017; Headey *et al.*, 2017; see also Chapter 2) and low-nutrient, highly processed foods have become relatively inexpensive. So-called 'sugar taxes' are becoming more and more popular – they are now present in over 20 countries – and, as the evidence shows (Nakhimovsky *et al.*, 2016) they can have an important role to play in reducing the consumption of drinks and other products with high levels of

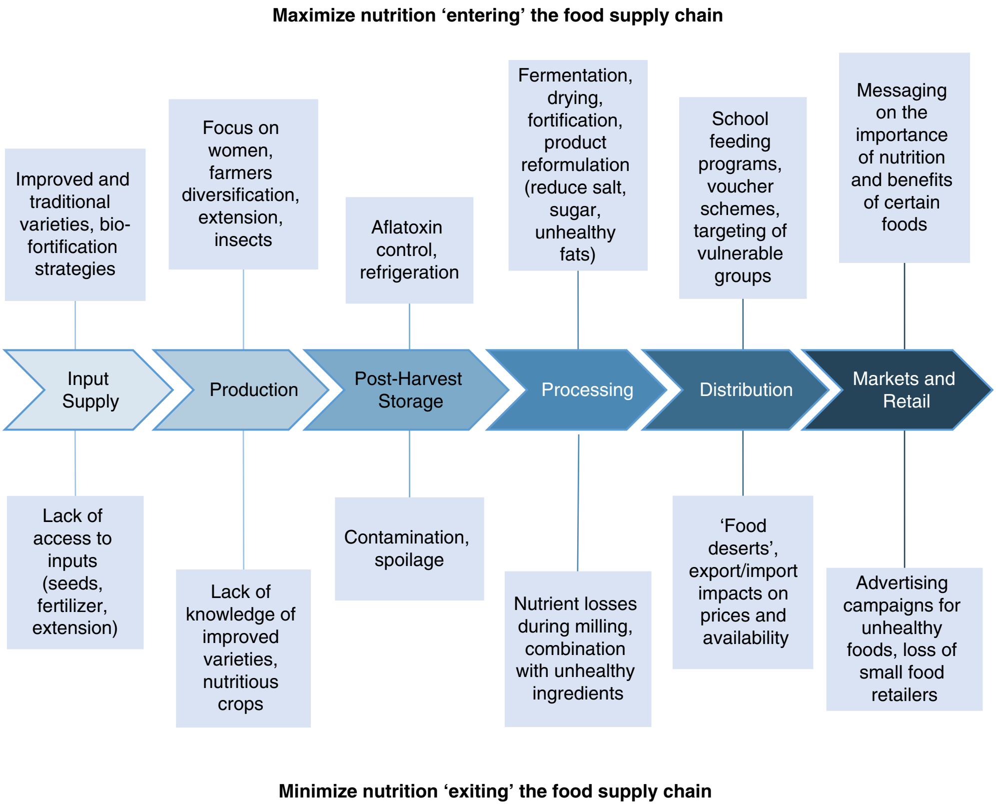

Fig. 11.2. Maximizing and minimizing nutrition entering and leaving the food supply chain. As food chains lengthen, the opportunities for nutrition to move in (and out) increase (Fanzo *et al.*, 2017, adapted by HLPE, 2017).

Table 11.1. Areas in which governments and businesses could work together to create a greater demand for nutritious food.

The goal	Example of action	What businesses would do	What governments and civil society would do
Improve demand for nutritious foods	More effective public nutrition campaigns	Contribute in marketing techniques that appeal to aspiration, emotion, desire	Contribute to the development of messages, identifying what resonates with values and culture
Incentivize consumers to purchase more of certain foods and less of others	Taxes on foods that are best avoided Subsidies on foods that are the best nutrition choice	Work on reformulation of products ○ Less fat/salt/sugar ○ More fiber, micronutrients	Build pressure on governments to pass laws Organize consumers and investors to reward/ pressurize businesses

added sugar. The evidence also shows (Afshin *et al.*, 2017) that reducing the price of healthy foods can increase their consumption. More can be done with sin taxes and virtue subsidies to change the price trajectories of different foods according to their nutritional contribution.

Improving the supply and affordability of nutritious foods

The second set of actions is around improving the supply and affordability of food (Table 11.2). This set includes efforts that aim to: (i) reach the

Table 11.2. Areas in which governments and businesses could work together to improve the supply of affordable nutritious food.

The goal	Example of action	What businesses would do	What governments and civil society would do
Reach entire population with better nutrient profile	Large-scale food fortification Support businesses that produce nutritious foods	Work with government to adopt and implement fortification Use the support to lower price, improve market penetration	Pass legislation to fortify staples Support the establishment of business enterprise funds
Improve the nutrition content of food products for specific populations	Development of low-cost nutrient-dense foods for specific food groups	Build demand for and lower the cost of (e.g.) home fortification for 6–24-month olds	Establish standards for the fortification, labeling and marketing of food products for specific populations
Reduce food loss in the food system	Strengthen cold chains: reach and cost	Develop new approaches and technology to reduce loss	Orientate new infrastructure investments in order to prevent nutrients from exiting the food value chain

entire population with a better nutrient profile; (ii) improve the nutrition content of food products for specific populations; and (iii) reduce food (nutrient) loss throughout the food value chain.

Large-scale food fortification of staple foods is an example of the first area, one with large benefit–cost ratios and proven impacts on nutrition status (Aaron *et al.*, 2017). Here millers or oil processors are required to add a micronutrient premix to their milled cereal or edible oils, often passing on minimal costs to consumers or having this cost subsidized by the government.

Another example is the provision of support to companies that want to expand their sales of nutritious foods. This support could take many forms, such as offering technical assistance on business plan development, the provision of small grants to overcome barriers to entry, and helping forge links to formal finance. Since 2013, for example, GAIN has been working with more than 500 small and medium-sized firms to get more servings of nutritious foods (such as beans, fish, peanuts and chicken) into markets in five countries in Africa and Asia, and to make those servings cheaper. Independent evaluations show some significant achievements. For example, one firm in Kenya has helped make tilapia fish affordable for 68% of the population (up from 49%) in the region where it is operating (Altai Consulting, 2017).

The support could also take inspiration from policy in other areas. For example, instead of export processing zones (whereby governments create favorable incentives for businesses producing goods for export in order to generate valuable foreign currency), policymakers could consider the creation of nutritious-food processing zones for businesses committed to producing these foods for domestic consumption at a certain price point. Here preferential rates on utilities and taxes could be offered.

The second area relates to improving the nutrition content of food products for specific populations. An example is the marketing and distribution of home fortification powders or sprinkles: how can these be made aspirational, safe, and affordable? Government promotion and quality standards are important to build demand and ensure the safe provision of home-based fortification solutions.

The third area relates to reducing food (nutrient) loss throughout the food value chain, primarily by introducing innovations for low-cost cold chains. Perishable food tends to be richer in micronutrients and fiber and also lower in added sugars, salt, and fat. Anything that can be done to reduce food losses during transport and storage is a big boost for preventing nutrients from leaving the food system. Simple technologies such as reusable plastic crates instead of woven baskets are proven (WRI, 2013) and the use of more sophisticated technology such as solar panels and high-quality insulation can help lower the costs of these vital chains.

Creating an enabling environment for businesses to improve nutrition

The third set of actions is around creating an enabling environment for businesses to re-orient their actions towards improved nutrition outcomes (Table 11.3). How easy is it for businesses to do positive things for nutrition and how difficult is it for them to do irresponsible things such as marketing foods high in sugars, salts, and trans fats to children? Examples relating to the ease of doing positive things for nutrition include policies that reduce or exempt tariffs on imported micronutrient premixes to be added to staple foods, and policies that reduce or exempt tariffs on imported insulation materials for cold chains. Accountability metrics such as the Access to Nutrition Index (ATNI) published by the Access to Nutrition Foundation in Utretcht (ATNF, 2018), are ways of faming good behavior and shaming irresponsible behavior. This independent initiative evaluates the world's largest food and beverage manufacturers on their policies, practices, and performance in relation to undernutrition and obesity and publishes the results every 2–3 years.

Workplace programs that aim to create a more pro-nutrition environment for employees are another potential intervention area. Actions include providing maternity leave, breastfeeding facilities, canteen food that uses fortified ingredients, and food-choice messaging and behavior-change sessions. Ways of making nutritious choices easier at point-of-purchase include simple 5-star or traffic-light ratings on the front of packaging labels, and quality seals that are intended to impart a certain level of confidence in consumers as to the nutritional value of their purchase. Supermarket layout designs that preserve profits but improve the probability of customers selecting nutritious foods are also viable options (Demmler *et al.*, 2017).

What is Holding Back Effective Public–Private Engagement to Improve Nutrition?

If there are so many possibilities to incentivize businesses to do more to improve nutrition status, why then do we not see more public–private engagements for nutrition? Why are research programs

Table 11.3. Areas in which governments and businesses could work together to strengthen the enabling environment for businesses to improve nutrition outcomes.

The goal	Example of action	What businesses would do	What governments and civil society would do
Improve ability of private sector to do good for nutrition	Taxes and subsidies Trade and finance	Inform governments of where the bottlenecks are	Apply a food-based dietary guideline lens to fiscal policy
Make it harder for private sector to behave irresponsibly	Monitoring and accountability metrics	Make public commitments and report on them	Help influence and track business commitments and ensure they – and the reporting against them – are widely shared
Improve the nutrition environment at work	Workplace programs	Work with governments to establish workplace guidelines that support nutrition plans	Tax breaks to companies that have a government-approved workplace program
Improve the nutrition environment at point of acquisition	Labeling Quality seals Supermarket design choices	Lead the way, to get a competitive edge Work with government to ensure alignment with government priorities	Legislation or championing of nationwide voluntary codes on labeling

and peer-reviewed literature quiet on this topic? Why are there so few university courses on this subject? What is holding us back (Haddad, 2018)?

There are many reasons. First, there are few documented examples of the impact that public–private engagement has had on nutrition. A review by Hoddinott *et al.* (2016) stated that 'there are few independent, rigorous assessments of the impact of commercial sector engagement in nutrition'. This means that we have few examples to emulate or from which to learn. We need more impact evaluations on these kinds of collaborations. We also need more learning from other sectors where public–private engagement is routine, such as in health and infrastructure (see, for example, the World Bank's Knowledge Hub on public–private partnerships in infrastructure). A dedicated knowledge hub for public–private engagements in nutrition that is quality screened but which goes beyond peer-reviewed literature would be a valuable resource for all.

Second, trust is low between public and private actors in the nutrition space. Fear of the unknown is one factor. There are differences in culture, language, and networks between the public and private spheres in nutrition, but these are fairly superficial and can be easily overcome, given the opportunity.

A more serious reason for low levels of trust is industry conduct on the marketing of breastmilk substitutes. The International Code on the Marketing of Breastmilk Substitutes is a well defined code that governs the way in which milk products aimed at 6–23-month-old infants and young children are marketed. It is designed to protect the exclusive breastfeeding of infants from 0 to 6 months and to protect breastfeeding as a complement to the introduction of other foods in the age range of 6 months plus. Anything that discourages breastfeeding is a count against a child's early nutrition and Code violations are serious – for the child, for the mother, and for the company. Many large companies have been found to violate the Code (Save the Children, 2018).

Another source of distrust is the marketing and promotion of sugary drinks, especially to children. Throughout Latin America, Africa, and Asia during the past 15 years, the level of consumption of these drinks has skyrocketed. Their increased consumption is associated with rapid rises in obesity in children and adults (PAHO/WHO, 2015). These companies do not assume any responsibility for the extremely adverse public health environment they are creating. They have the potential to play a much more positive role in improving nutrition outcomes, but to craft those opportunities, stakeholders must engage with them.

These two hotspots have received a lot of attention, and rightly so. But the attention has also blinded us to the potential opportunities to improve nutrition in other domains of the public–private space. For example, mobile phone technology has the potential, under the right circumstances, to improve the reach of nutrition messaging to low-income families while increasing the highly prized traffic flow to mobile phone providers (Turner *et al.*, 2015; Barnett *et al.*, 2016). Marketing and advertising companies have the potential to create markets to provide services to the public sector to dramatically improve the 'stickiness' of mass-media public health sector messaging around nutrition. Cold chain and logistics companies could develop relatively low-cost technologies and practices using solar energy, repurposed storage containers, and low-cost insulating materials to reduce food losses during storage and distribution. Small and medium-sized businesses in horticulture and aquaculture could make their products more available, more affordable, and more profitable, if they had some technical assistance and a small-scale investment facility to support their ambition. Many of these opportunities will involve working with small, medium, and large national companies. The power imbalance between the multinationals and governments does not have to rear its head in every public–private engagement.

Third, the potential to do harm makes us rightly cautious, even when working with companies with good track records on nutrition. Few in the private sector are willing to advance public health outcomes if there is a significant commercial loss involved – that is not sustainable financially. But there are many in the private sector who are willing to work hard to adjust, adapt, and evolve to find overlaps between the two goals. They are the ones with whom partnering is ideal. The accountability measures highlighted above will help reduce the risk entailed with embarking on such a partnership.

Conflict of interest guidelines will help to uncover multiple aims and interests on all sides and to design governance arrangements that tell us when public health goals are in danger of being compromised for other goals.

Finally, there is a dearth of opportunities for public and private stakeholders to talk. Overcoming this hurdle is foundational to resolving many of the issues already mentioned. Talking is the way we get the measure of a potential partner. Do they share our values, aims, and ways of working? Will they act for nutrition when no one is looking? Failing to talk leads everyone into a low-level equilibrium where we do not build up an understanding of who is a potentially valuable partner, we do not build up trust, we do not work with potentially valuable partners, and we do not resolve any hard boundary issues that exist.

How do we break out of this dialogic impasse? There are a number of practical solutions. Conference organizers could incentivize panels at conferences or meetings to have a mix of public and private participants on them. Research funders could design nutrition research program calls that encourage public and private organizations to prepare joint proposals. Employers could launch staff exchanges between companies and public-sector organizations. Universities could offer short courses that bring together professionals from the public and private sectors to learn together from instructors who are also drawn from these two worlds. The possibilities to promote public–private dialogue for improving nutrition are endless. So too are the opportunities missed by failing to do so.

Conclusion

Poor diets are the main cause of ill health in the world and are at the heart of all forms of malnutrition. Food systems are key shapers of the choices consumers face and the choices they make. Governments set the rules around food systems, civil society shapes the norms, and businesses are the main investors within them. Hence food systems will not deliver more affordable nutritious food unless businesses are seen by governments as a part of the solution and not only as a part of the problem.

This chapter has outlined numerous ways in which businesses, working with governments and civil society, can improve nutrition. But they need to be incentivized to do so, as commercial imperatives will not always overlap well with public nutrition goals. This chapter has detailed the opportunities governments have on hand to deploy policy carrots as well as policy sticks to encourage businesses to do more good things for nutrition and fewer bad ones. Governments need to actively deploy these carrots and sticks. If they fail to do so, opportunities to advance nutrition will be missed and the most vulnerable will lose out.

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A community mobilizer in Indonesia. Leadership is pivotal at all levels. (Minzayar Oo/Panos/Save The Children)

12

Governance and Leadership in Agri-food Systems and Nutrition

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Introduction

A decade ago, the governance of the international nutrition system was found to be 'fragmented and dysfunctional' in one of several reviews in the seminal *The Lancet* Nutrition Series (Morris *et al.*, 2008). A lot has happened since then, with global political attention to nutrition being greater now than at any time since the World Food Conference held by the United Nations in Rome in 1974.

This chapter first reviews the relationship between governance systems and processes (at various levels) and the nutrition sensitivity of agri-food systems, before reviewing the role of leadership in orienting such systems toward nutrition goals.

Governance, Agri-food Systems and Nutrition: What Are the Links?

In 1990, UNICEF laid out a comprehensive framework for understanding the multiple drivers of child and maternal undernutrition at basic, underlying and immediate levels (UNICEF, 1990). In 2013, the second *The Lancet* Maternal and Child Nutrition Series further adapted this framework to highlight three levels of action to achieve optimal child nutrition and development: (i) the design, implementation and scaling up of a package of core 'nutrition-specific' interventions; (ii) the embedding of nutrition objectives and actions within a range of broader sectoral actions (including agriculture and agri-food systems) to foster 'nutrition-sensitive development'; and (iii) the creation and sustenance of an 'enabling environment' for nutrition that is crucial for all three levels of action (Black *et al.*, 2013).

The concept of enabling environments went beyond a focus on basic causes of undernutrition such as unequal access to resources (still seen as critical in shaping underlying drivers), to incorporate governance concerns (Box 12.1). Key ingredients of such environments include: (i) knowledge, data and evidence and its effective framing and communication; (ii) political commitment, effective governance and sound policy; and (iii) leadership, capacity, and financing (Gillespie *et al.*, 2013).

In parallel, work on obesity has also identified it as a complex, multifactorial problem with genetic, lifestyle, cultural, medical, and social drivers (Lachal *et al.*, 2013) that are in turn fueled by rapid economic, societal, and cultural change. Swinburn *et al.* (1999) first coined the term 'obesogenic environment' to refer to 'an environment that promotes gaining weight and one that is not conducive to weight loss' within the home, workplace or society. Work on obesogenic environments has, as with work on undernutrition, increasingly focused on the

Box 12.1. What is 'good governance' for nutrition?

The concept of governance has many definitions. The United Nations (UN), for example, defines national governance as:

> … the exercise of economic, political, and administrative authority to manage a country's affairs at all levels. It comprises mechanisms, processes, and institutions through which citizens and groups articulate their interests, exercise their legal rights, meet their obligations, and mediate their differences.
>
> (UN STT, 2012)

Most definitions incorporate institutional structures, relationships between actors and/or organizations, decision-making processes, and incentives. Governance importantly encompasses the capacity to act, the power to act and the commitment to act; it requires accountability, responsiveness and transparency (Gillespie, 2013).

Governance is relevant at many levels, from global to local. In a recent review, the UN's Standing Committee on Nutrition defines 'global nutrition governance' as the network of actors whose primary function is to improve nutrition outcomes through processes and mechanisms for convening, agenda setting, decision making (including norm-setting), implementation and accountability (UN SCN, 2017). 'Governance *for* nutrition', on the other hand, is defined as the process by which impact on nutrition by non-nutrition policies (e.g. policies in agriculture, education, employment, health, environment and trade) is leveraged or mitigated.

governance, political and policy drivers which shape such environments – questioning the assumption that obesity is simply down to poor individual choices.

Policy and institutional environments that shape agri-food systems and their nutrition outcomes may thus be characterized as enabling (with regard to positive outcomes), or 'disabling' (Gillespie and van den Bold, 2017), but they are far from ever neutral.

Governance, Power and Accountability: Words and Actions

> Accountability is ultimately about governance and power and determines how and why decisions are made, who makes decisions, how power is used, shared, and balanced, whose opinions are important, and who holds whom to account.
>
> (Swinburn *et al.*, 2015)

Food systems are complex (see next section), and the global institutional architectures for agriculture and nutrition have many nodes of planning and action: national governments, civil society (global and national), international and regional organizations (including UN agencies, development banks, African Union), bilateral donors, charitable foundations, international research organizations, academia and private sector companies.

Linking agriculture and nutrition in policy and programming faces structural, operational, and organizational hurdles. The two sectors are usually housed under different bureaucratic structures and are allocated significantly different levels of resources, But in any analysis, it is also crucial to go beyond the architecture and artefacts of governance (e.g. national nutrition council, existence of policies, or codes of conduct) to look at what is actually happening with regard to implementation of policies and regulations. Governance in this respect cannot be apolitical – it has to relate to a particular goal (in this case, helping agri-food systems to become more nutrition sensitive). There are both winners and losers and a variety of such actors looking to influence the outcomes of policy processes in their own interests. In analysing this, many approaches to nutrition governance, which could similarly apply to agriculture governance, have also employed the concept of political economy – defined as 'the competing interests, incentives, and ideologies of a range of different actors with direct and indirect interests in nutrition, and the resultant inequalities' (Nisbett *et al.*, 2014, p. 422).

Actors respond to incentives, some of which are pro-nutrition, and some of which are not. Strong governance is particularly important where there are asymmetries of power and incentives – for example, between governments and multinational companies. Civil society and social activism can help rebalance power across the agri-food system towards better nutrition, especially for the most nutritionally vulnerable who tend to be the least empowered.

Governance and accountability mechanisms are thus crucial for identifying, preventing and addressing conflicts of interests between public and private actors; for example, where the incentive to make profits may lead to practices that damage nutrition.

How are Nutrition and Agri-food Governance Measured and Monitored?

Different approaches, methods and indicators have been employed in recent years to measure governance and facilitate accountability. In regards to nutrition, in 2012, the World Health Organization (WHO) developed a 'Landscape Analysis' mapping tool to assess nutrition governance in different countries. Countries with strong nutrition governance and a readiness to accelerate action in nutrition were defined as having most or all of the following traits: political commitment and awareness of nutrition; focused policies and regulation at a central level, with supporting plans and protocols at subnational level; resource mobilization at central level and budget provision at subnational level; coordination of nutrition activities at all levels; involvement of partners; support to districts and facilities; trained staff with appropriate skills at all levels; capacity and motivation of staff; quality of services and follow-up, management, information systems and supplies in place; and community engagement strategies (WHO, 2012). Other innovative tools are available to stimulate, monitor and build commitment and accountability. A Nutrition Commitment Index, for example, has been developed by the Institute of Development Studies for cross-country and within-country comparisons over time (te Lintelo *et al*., 2013). This measures political commitment to tackle undernutrition in 45 developing countries by focusing on a series of policy, legal and spending indicators.

Although there has been an upsurge in research and action on the nutrition outcomes of agriculture and agri-food systems, the governance dimension remains under-studied. A 2012 assessment of research on the agriculture–nutrition nexus identified eight clear research gaps, one of which was:

> … governance, policy processes and political economy as it relates to the development of agriculture-for-nutrition policies and programmes, the ability to implement them (and scale up) and for them to achieve their stated goals once implemented.
>
> (Turner *et al*., 2013)

Only six of 151 studies investigated governance, at that time. Since then, there has been some progress.

The two 'Leveraging Agriculture for Nutrition' initiatives (the multi-party consortium LANSA for four countries in South Asia, i.e. Afghanistan, Bangladesh, India and Pakistan; and the IFPRI/FAO collaboration LANEA for East Africa covering Kenya, Uganda and Ethiopia) investigated stakeholder perceptions of the governance of agri-food systems in six high-burden countries in 2014 (Table 12.1), applying the distinction between the building of political momentum and its translation into effectively implemented, scaled-up policies and programmes that generate impact on the ground (Gillespie *et al*., 2013).

Recent studies, though not specifically about agriculture and nutrition linkages, draw insights about multisectoral governance arrangements that are highly pertinent to the topic. In a recent study of nutrition governance metrics in Nepal, stakeholder interviews were structured around three topical categories that drew on findings of the WHO's landscape analysis and its 2013 global nutrition policy review (Webb *et al*., 2016). These are as follows:

1. Commitment to nutrition (do policies and instruments exist? Are civil servants outside the health sector willing to adopt nutrition as a core responsibility? Are institutional management structures able to accommodate the inclusion of nutrition in annual work plans?).
2. Capability to implement pro-nutrition policies and programs (adequate budgetary, technical, and human resources to do the jobs required).
3. Collaboration (management support for cross-sectoral engagement toward common goals, coordination mechanisms, and institutional incentives for the adoption of jointly owned goals).

One key finding was the strong stakeholder support for mandatory mechanisms for collaboration among respondents in non-health sectors. Many non-health professionals wanted to do more 'for nutrition' but felt that their management support systems and incentives were not conducive. This sentiment could presumably be applied to agriculture professionals. The review also found that the food security and agriculture sectors mostly devoted their policy work towards

Table 12.1. Summary of key issues in governance of agri-food systems in six high-burden countries (LANSA, LANEA). (Source: Gillespie *et al*., 2015.)

Building commitment	Turning commitment into action and impact
Horizontal (cross-sectoral) coherence	Vertical coherence (national to community)
Priority-setting and policy formulation processes	Ensure incentives for implementation
Address production bias	Clarify and ensure accountability at all levels
Identify mechanisms for communication and coordination	Decide whether to integrate or co-locate programs and interventions
Decision-making incentives (for change)	Empower women through agriculture
Leadership/champions	Engage private sector and other development partners, based on comparative advantage
Pro-nutrition legislation	
Global and regional conferences and movements	Forums for sharing lessons on what works

research, provision of seeds, irrigation, and rural infrastructure with the goal of increasing farm level income and outputs; few agriculture policy goals explicitly mentioned nutrition.

In another recent study of nutrition governance in several African countries, Pelletier *et al*. (2018) viewed the 'ecosystem' of individuals and institutions in multisectoral governance as a complex adaptive system which 'makes it difficult to govern exclusively through formal and hierarchical (legal and bureaucratic) institutions commonly established to address the problem (e.g. multisectoral coordinating committees)'.

In 2016–2017 there were several high-profile publications focusing specifically on nutrition and food systems, including the Global Panel on Agriculture and Food Systems for Nutrition and the High Level Panel of Experts on Food Security and Nutrition (HLPE, 2017). The latter portrayed the latest adaptation of a conceptual framework of the food system (Fig. 12.1). This highlighted an array of drivers conditioning the operation of food supply chains, food environments, and consumer behaviors leading to effects on diets and to various nutrition and health impacts. This system is amenable to political, program and institutional actions that can steer the outcomes of this system towards the UN's 17 Sustainable Development Goals (SDGs).

In this framework, governance and leadership are viewed as key political drivers and actions. Most of the concluding section of the report ('Translating Evidence into Action') refers to the challenge of strengthening enabling environments and governance within this system – along with the pivotal need for strengthened leadership.

How Important is Leadership in Improving Nutrition Outcomes of Agri-Food Systems?

Leadership has been identified as a central element of effective governance for nutrition in most of the nutrition, food systems and agriculture governance frameworks reviewed. The role of individual leaders and champions has also

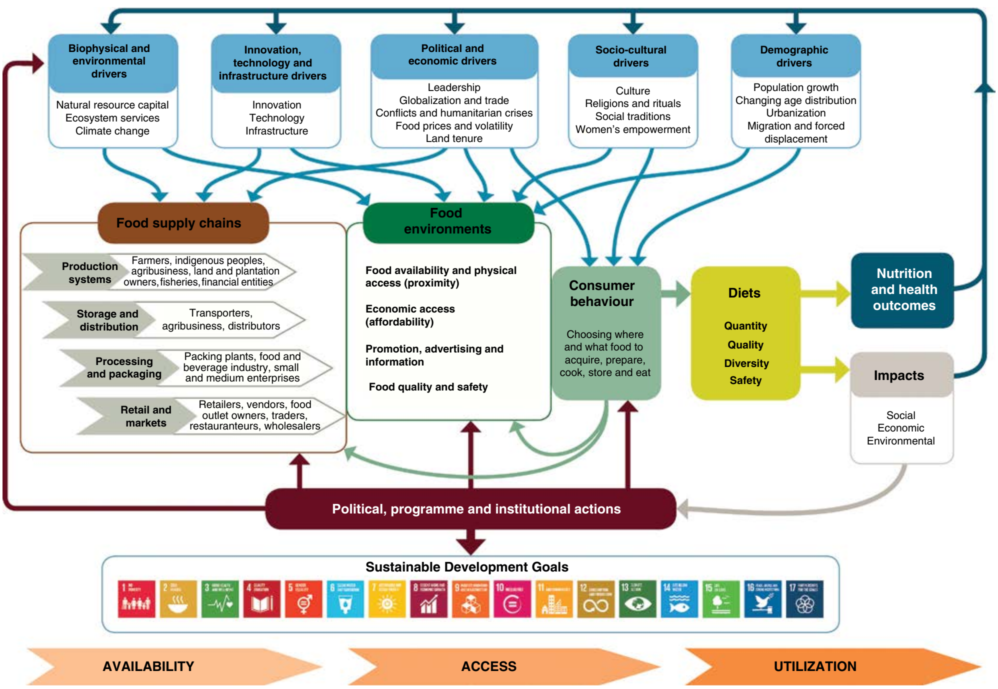

Fig. 12.1. Conceptual framework of food systems for diets and nutrition (HLPE, 2017).

been highlighted as a critical element in many positive 'stories of change' or country case studies of rapid improvements in nutritional status and food security. In some policy fora, the focus has been directed towards the need for higher-level political leadership on malnutrition. But research has also now highlighted the importance of leadership throughout nutrition, agriculture, and food systems and in particular the role of individuals working at ground level, as well as these executive levels, who collectively contribute to the functioning of systemic leadership (Nisbett *et al.*, 2015). Such individuals tend to be adaptive, strategic boundary spanners (Pelletier *et al.*, 2018) or, more simply, those who make the effort both to understand and to speak the language of others. Given the multi-causal and systemic nature of malnutrition, this process of translation is most effective when it is genuinely multisectoral and politically savvy.

Effective leaders have been shown to be those who can understand both the available contributions and the obstacles to effective action within public and private sectors. They have a good understanding of the policies and programs that exist in their own field, whether agriculture or others, as well as the potential contribution of changes to the agri-food system and in other potentially nutrition-sensitive sectors such as social protection. They are driven not only by general notions of 'what works' (i.e. what the evidence tells us) but also 'what can work in a given situation'(i.e. both politically and contextually). Poor leadership is that which tries to impose a package of solutions on multiple contexts without adaptation to local ground realities.

The actual attributes of leaders have been reviewed in research in which 89 individuals identified as leaders in four countries experiencing a high burden of nutrition in South Asia (India, Bangladesh) and sub-Saharan Africa (Kenya and Ethiopia) were interviewed (Nisbett *et al.*, 2015). These and other attributes associated with leadership were identified in a recent guide by Transform Nutrition and Scaling Up Nutrition (TN and SUN, 2017) and summarized as follows:

- Skills required to effectively operate within networks:
  - advocacy;
  - knowledge dissemination and communication;
  - relationship-building;
  - consensus-building;
  - risk-taking;
  - diplomacy;
  - ability to overcome opposition;
  - ability to navigate boundaries between social, political and professional groups; and
  - ability to understand (and navigate) policy and practice environments.
- Skills required to shape one's network:
  - ability to inspire and motivate;
  - ability to unleash the potential of others; and
  - ability to focus their own and other members' energy on achieving collective results.

Leadership has traditionally been associated with power – with formal authority, or the power that accrues to the holder of charisma or reputation. Whilst such leadership is surely important, the attributes highlighted above also demonstrate that, for most people, leadership is something that they develop over time in building respect amongst peers and in continually attempting to understand others' positions, to work through others and to openly self-reflect and adapt. In so doing, they build a following, and can become more effective than those who simply rely on formal power alone.

Shining a Light on Successful Leadership

Examples of successful leadership in nutrition, food systems and agriculture have grown in recent years, with the appearance of a number of awards for successful nutrition champions, such as that run by the Transform Nutrition research consortium, which has been taken up by the Scaling Up Nutrition (SUN) movement. Such initiatives have brought public recognition to a range of new leaders at all levels, from a 15-year-old youth parliamentarian in Zimbabwe, to high-level political leaders, to mid-level career bureaucrats who have driven through change (SUN, 2017).

The work of some of these leaders and others has also now been well documented in nutrition policy research and has contributed to the key attributes listed above. Understanding how leaders operate – the particular skills they have in crossing boundaries, communicating, networking and 'getting things done' – is as important as identifying who they are. But although particular individuals stand out, the research also demonstrates that such individuals are not operating in a political vacuum. Not only do they know how to work through others, but also they have often been brought to their positions championing agriculture, nutrition and food security via either political necessity or the encouragement or advocacy of others.

Bangladesh (see Chapter 15) and Ethiopia (see Chapter 16) represent two examples where political necessity has driven broader food and agricultural policy leadership, as a result of significant famines in their history directly linked to, or at the time of, political change and upheaval (Davis *et al.*, 2016; Warren, 2016). Both countries have made significant strides in increasing agricultural production and improving broader food security as well as broader nutritional outcomes.

In Bangladesh, agricultural growth during the past four decades has been coupled with increased food consumption, GDP growth, and poverty reduction. Significant improvements in nutrition have yet to be achieved, but the country's policy processes and outcomes have shown a growing recognition of the links between agriculture and nutrition. The 1997 National Food and Nutrition policy, which recognized nutrition as a human right, was formulated in consultation with experts in food and agriculture, among other sectors (Naher *et al.*, 2014). The 2008–2015 National Food Policy Plan of Action and the Bangladesh Country Investment Plan on Agriculture, Food Security, and Nutrition have prompted the establishment of several large agriculture-for-nutrition interventions (van den Bold *et al.*, 2015). The Department of Agricultural Extension is beginning to integrate concerns about balanced diets. And civil society and the media seem to have played a strong role in establishing accountability mechanisms for coordination between the sectors. Much work remains in the way of building up research capacity and other areas (van den Bold *et al.*, 2015).

In Ethiopia, country-level leadership continues to ensure that these sectors remain prominent – including, for example, the Ethiopian Ministry of Agriculture's efforts via its twin-track Productive Safety Nets Program (PSNP) and the Agricultural Growth Program (focused on high production areas) (Warren, 2016). Since 2005, PSNP has provided food security and an avenue for distributing improved agricultural technologies, in addition to (in its fourth phase launched in 2016) nutrition-friendly provisions such as connecting clients with nutrition and health services, prenatal and postnatal care, and behavior change communication (Warren, 2016; see also Chapter 16). The Agricultural Growth Program II includes nutrition capacity building and behavior change communication on dietary diversity. The enabling environment for supporting agricultural extension agents still needs to be improved through better nutrition training (Beyero *et al.*, 2015). Ethiopia's revised National Nutrition Plan, launched in 2015, includes agriculture among other sectors and sets indicators for its contributions to nutrition.

Country-level stories of change in nutrition can offer lessons for how to advocate for stronger agriculture–nutrition political processes and outcomes. In Peru, the country's rapid reduction of undernutrition in 2005–2011 has been analyzed as resulting from the executive leadership displayed by Peruvian politicians on all sides – particularly in the adoption of the electoral campaign '5 × 5 × 5' (reduce stunting for the under 5s by 5 percentage points in 5 years) and the subsequent government programs put in place to achieve this (Mejia Acosta and Haddad, 2014). But to attribute this change to the leadership of sole-acting individuals such as President Alan Garcia alone would be a misrepresentation of the process. A civil society coalition advocated for this focus in the first place and then held the government to account for its commitments.

A further example exists from the Indian state of Maharashtra, where the actions of a mid to senior level official to focus on particular pockets of deprivation and malnutrition in *adivasi* ('scheduled tribe') areas has been lauded as a factor leading to the state's focus on nutrition via a 'Nutrition Mission' and associated with the state's subsequent declines in child stunting (Haddad *et al.*, 2014; Nisbett and Barnett, 2017). Again, this individual's actions were supported by a sustained campaign and focus on malnutrition from civil society activists, UNICEF, the media, and even the judiciary.

Civil society and non-governmental organizations (NGOs) often add important leadership roles to the advocacy efforts documented here in terms of their drive to innovate at a community level and provide examples that can be scaled up elsewhere. One such leader recognized by the Transform Nutrition Consortium is Debjeet Sarangi, who has worked with landless and marginal farmers and communities in Odisha, India. His organization, Living Farms, uses participatory methods to diagnose and improve food security, agricultural practices, nutritional and child survival outcomes. Mr Sarangi's use of networking and advocacy to local officials and the collection and sharing of data also highlights use of the skills and attributes highlighted above (Nisbett *et al.*, 2016). Similarly, the NGO Helen Keller International's experimentation with, and participation in, the evidencing of enhanced homestead food production over three decades in multiple countries has become an important part of the global evidence base on what works in nutrition-sensitive agriculture (Yosef, 2016).

Where is Leadership Currently Lacking?

Malnutrition exists in many forms. Globally, it is estimated that 155 million children suffer from stunted growth and cognitive development as the result of chronic malnutrition, while a further 52 million suffer from severe acute malnutrition (UNICEF *et al.*, 2017). Rates of micronutrient deficiency are even higher, with around 2 billion people estimated to suffer from at least one form. Rates of overweight and obesity amongst both children and adults are already endemic in richer countries and are becoming more common among poorer populations: according to the 2017 estimates by WHO, UNICEF and World Bank, at least one in ten children under the age of five is already overweight in Northern Africa, Central Asia and Southern Africa. If leadership is lacking on any one of these forms, it is in even sparser supply when it comes to tackling the issues together, despite their common causes. This leadership gap extends to the kinds of systemic leadership described above – there are still very few people willing and able to work across the kinds of food system and health system boundaries that need to be bridged if we are to tackle the causes of undernutrition and overweight and obesity together.

At a political level, this may be due to the fact that the political decisions required are difficult. They may well involve standing up to vested interests amongst producers, consumers and companies who benefit from the status quo of a food system either failing to deliver enough quality food to the right places, or delivering micronutrient-poor, calorifically dense and otherwise unhealthy, yet still craved-for, food in ever larger quantities. But even at the levels of technical, practical and research expertise, there are still significant challenges in adequately linking together nutrition and agriculture actors, who are often working to quite different agendas (e.g. public health/child survival versus food security) and where a 'food-first' focus on mass food production may predominate (c.f. Pelletier *et al.*, 1995) as a significant political pressure.

At a country level it is hard to find examples of the kind of multifaceted, ambitious and brave leadership these entrenched issues call for. But increasingly such leadership is being demonstrated by municipal leaders, with cities such as Amsterdam and Belo Horizonte revealing the ways in which public health, education, food distribution and retails, spatial planning, fiscal measures and other local legislative powers can be brought together to create more healthy eating environments for urban citizens (IPES-Food, 2017). More such examples are needed to indicate future pathways for countries wanting to transition from food-insecure environments to healthy food environments but without landing in the position that most Organization for Economic Cooperation and Development (OECD) countries find themselves in terms of diet-related disease. While this may be the focus of the nutrition- and health-related SDGs, such multifaceted leadership is also currently lacking in terms of the global institutions supporting agri-food and nutrition, many of which are still stuck on one side or another of dealing with either famine or undernutrition or the consequences of overweight and obesity.

How Can Leadership be Nurtured and Supported?

A recent 'toolkit' produced by Transform Nutrition and the SUN movement secretariat focuses on the various ways in which potential leaders and champions can be identified, nurtured, supported and sustained (Fig. 12.2). This builds on the work of various leadership initiatives and training programs such as the African Nutrition Leadership Programme, and also work by Nisbett *et al*. (2015) to produce a framework which focuses on how to turn key individuals at senior, middle and grassroots levels into champions, leaders and advocates for change. The framework stresses the need for different strategies for different targets – reaching key high-level individuals via others close to them, for example, or finding ways to expose them to the realities of malnutrition via field visits. But it also stresses the importance of leadership being held to account by and emerging from those communities suffering most from malnutrition. Thus, this framework ties in centrally to concepts of commitment, accountability, and visibility discussed so far. Sustainable leadership is that which exists in networks of individuals rather than one or two charismatic champions who may well move on. Therefore, appropriate strategies to work at each of these levels is an important part of an effective leadership strategy.

Broader leadership capacity-building initiatives exist, including those that have focused on

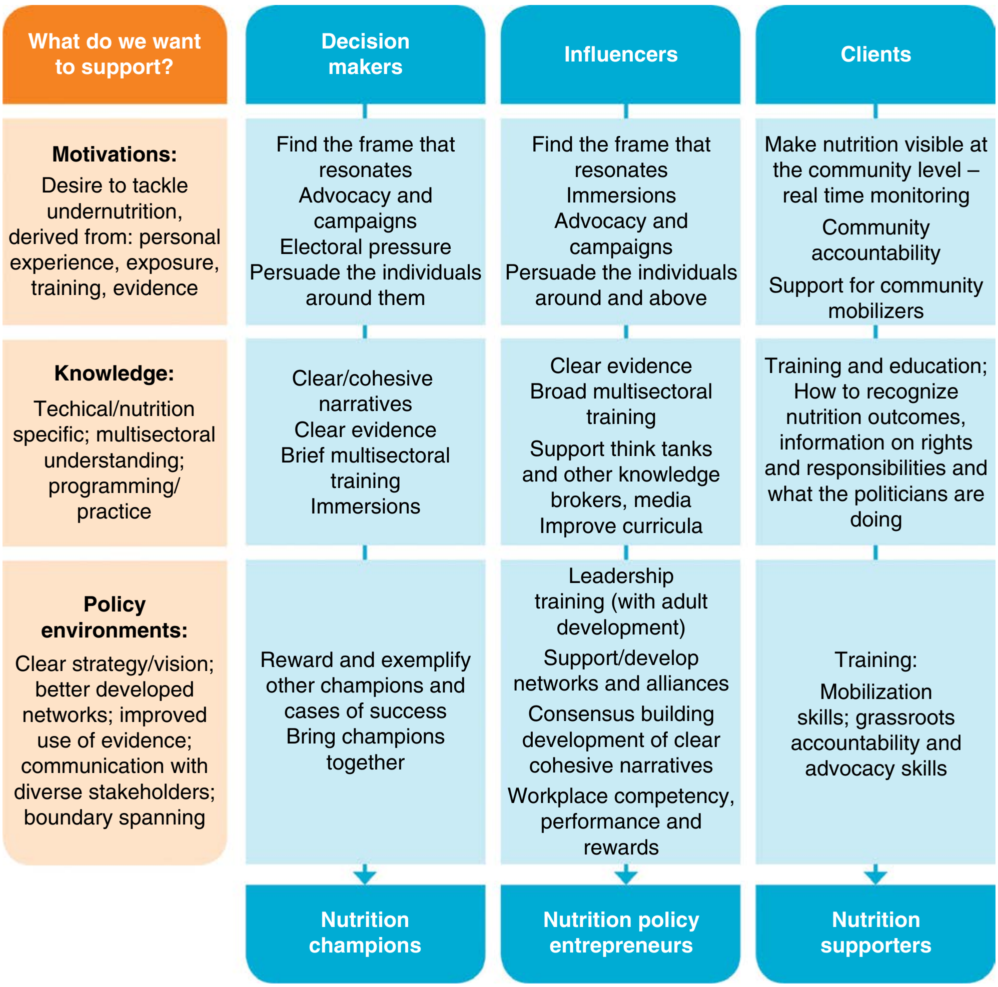

Fig. 12.2. Theory of change for supporting nutrition leadership (TN and SUN, 2017, adapted from Nisbett *et al*., 2015).

the perennial challenge of ensuring agricultural policy and interventions make a greater contribution to nutritional outcomes. This includes, for example, the sub-regional training/workshops provided as part of the Comprehensive Africa Agriculture Development Programme (CAADP) Nutrition Capacity Development Initiative: a unique initiative designed to help African countries integrate nutrition objectives and activities in their National Agriculture and Food Security Investment plans. This reached around 200 participants composed of multisectoral country teams from over 15 countries (Dufour *et al.*, 2013). Further such measures are needed in the future, including those that focus not just on technical country leadership but also on a younger generation which might be expected to form a leadership cadre in these fields in future.

Looking Ahead

Governance and leadership in the agri-food system cannot be treated separately – it takes leadership to implement effective systems of governance that realize results on the ground. It takes a certain type of leadership to broker the alliances and trade-offs and to take the difficult decisions that lead to more equitable and sustainable food system outcomes. Neither governance nor leadership is apolitical in this respect: policy goals are always political goals and demonstrating leadership in advocating for particular (more nutritionally equitable) policy agendas requires a well honed ability to negotiate between the competing interests suggested by the concept of political economy. Understanding governance frameworks helps us better understand the venues for these negotiations and trade-offs – which occur not only in policy/agenda setting spaces, but also within implementation structures, within knowledge and evidence production and framing and within local communities. Future research on governance and leadership needs to further elaborate on the confluence of a variety of different nutritional and political contexts, governance systems and styles and types of leadership within these different spaces and the resulting impact on nutritional outcomes.

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An agriculture extension worker stands beside a community garden in Uganda. Integrating agriculture and nutrition into extension work is an ideal way of reaching remote communities with personalized services and education. (Rotary International)

13

Building Capacity to Link Agriculture and Nutrition

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Introduction

Ending malnutrition is critical for both economic and human development (Shekar *et al.*, 2017). To improve nutrition globally by 2025, the international community, as represented by 176 member countries of the World Health Assembly, endorsed the first-ever global nutrition targets in 2012. These targets focus on six key areas: stunting, anemia, low birthweight, childhood overweight, breastfeeding, and wasting. To achieve these targets and reduce malnutrition rapidly, countries need to invest in both nutrition-specific and nutrition-sensitive interventions, the latter involving sectors such as agriculture (Hoddinott, 2016).

Agriculture has traditionally comprised a significant share of national economies. It holds a critical role in low-income countries: in 2016, it accounted on average for 30% of low-income countries' gross domestic product (GDP) and employed a large portion of their population (World Bank, 2016). Growth within the agriculture sector can potentially have a greater impact on people's welfare, including their health and nutrition, than growth in GDP (Webb and Block, 2010; Gillespie and Charlotte, 2016). Agriculture can play three interlinked roles to improve nutrition outcomes by providing nutritious food, being a source of income for people to buy nutritious food and health care, and empowering women, if agriculture interventions are undertaken in a gender-sensitive fashion (Hoddinott, 2016). However, agriculture's potential to reduce malnutrition is currently not being fully realized, due to the large disconnect between agriculture and nutrition. This gap can be attributed to inadequate capacity of both sectors to jointly address the current challenges.

Gillespie *et al.* (2013) argued that three critical factors are essential to build and sustain an enabling environment for nutrition: (i) political and governance; (ii) knowledge and evidence; and (iii) individual, organization and systemic capacity and financial resources. Despite continued interest in agriculture–nutrition linkages, lack of capacity at individual, institutional, and system levels prevents many developing countries from reducing hunger and malnutrition.

Several factors prevent the successful development and implementation of multi-disciplinary capacity for agriculture, nutrition, and health. First, development goals are often pursued without giving due consideration to the need to integrate the food and agricultural system with health and nutrition outcomes. This is partly due to insufficient development of concepts and methods for analyzing integrated approaches to address food security and nutrition challenges. Equally as important, experts in both fields are usually trained solely within their own disciplines. At the individual level, there is a lack of formal education among graduate students and limited capacity of extension-service providers. At the institutional level, there is a lack of capacity to conduct cross-disciplinary research, provide nutrition-friendly agriculture extension services, and offer university-level education and training on agriculture–nutrition links. This siloed approach to training and education means that the interactions of agricultural production systems with health and nutrition systems are not fully understood by the people responsible for designing and implementing policies and programs.

Such challenges carry over to the global level. At the system level, there is a lack of coordination among stakeholders and integration both vertically (national to local) and horizontally (across sectors) to implement multisectoral policies and programs. To date, there have been very few systematic efforts to strengthen the multi-disciplinary capacity of the development community to address the problems of food and security, malnutrition, and poverty.

This chapter focuses on how building and strengthening capacity at the individual and institutional levels can in turn strengthen agriculture–nutrition linkages. It focuses on two specific aspects of capacity. First, it highlights ways in which universities, organizations, and governments are working to improve cross-sectoral educational opportunities for students. Second, it explores how extension and agricultural services could be made more nutrition-sensitive by improving their content or the capacity of extension workers through formal education and training, in turn improving farmers' understanding of agriculture–nutrition linkages within production, on-farm processing, storage, and marketing; and consumers' purchasing decisions (FAO, 2014). Finally, it reflects on lessons that can be learned from efforts to increase capacity at these critical levels.

The Emergence of Integrated Agriculture and Nutrition Curricula

Nutrition and agriculture interventions and policies are the main avenue for delivering nutrition and agricultural knowledge and services to vulnerable populations, and thus making a dent in malnutrition. These policies and programs are designed and implemented by professionals, most of whom have been trained in formal university settings. Thus, incorporating nutrition education into agricultural educational programs has enormous potential to effect positive change in the way in which these professionals carry out their day-to-day work. By developing cross-disciplinary programs, universities can shape well rounded professionals who can work as extension workers, healthcare providers, or nutrition counselors, and help improve linkages among agriculture, nutrition, and health (Fan *et al.*, 2012).

There is currently much room for progress. For example, Babu *et al.* (2016) evaluated the curricula of three state agricultural universities in India (in Tamil Nadu, Andhra Pradesh, and Bihar). Results of their study showed the absence of nutrition as a subject in all three curricula, a critical oversight when considering that these universities are responsible for training current and future agriculture extension agents in very populous Indian states. The study also found that mid-level training of agricultural extension workers did not include courses on nutrition either, resulting in a 'nutrition vacuum' within the extension system. This study provided a conceptual framework for developing a curriculum to improve agriculture–nutrition linkages, a strategy to develop a nutrition-smart agricultural extension curriculum, and a curriculum strategy at the district level using the nutrition security conceptual framework. The authors also provided lessons for developing countries to integrate nutrition transformation objectives into extension and advisory services (EAS).

The University of Ghana hosts a 4-year-long extension program focusing on nutrition education and income-generation activities. Along with theory, this program integrates practical aspects of EAS, including a semester-long practical training exercise where students engage with families in rural communities. Graduates from this program work with agriculture EAS departments and support extension agents focusing on nutrition education at the grassroots level. Despite this effort, results from a study examining agriculture–nutrition linkages in Ghana showed that a narrow view of nutrition persisted within government bodies. There was still an inadequate capacity of nutrition trainers working at the Ministry of Agriculture, limited or lack of formal nutrition courses, lack of diversity in topics covered within the courses available, inadequate infrastructure for nutrition training, and a vague understanding of the role of agriculture and its impact on nutrition (Fanzo *et al.*, 2013).

In addition to incorporating nutrition courses into agricultural curricula where nutrition content is currently absent, programs that do include nutrition content need to strengthen their assessment of nutrition-sensitive agriculture competencies among current and recently graduated students. Abebe *et al.* (2017) assessed the level of nutrition-sensitive agriculture competencies of graduating agriculture students in Ethiopia. Results of the study showed that only 49% of the students demonstrated mastery of nutrition competencies. Female students and students from regional colleges scored much lower than their male counterparts and those studying in federal institutions. These findings point to a need to strengthen curriculum, build the capacity of educators, and provide additional support to female students and students studying at regional universities to improve their contributions to multisectoral efforts to end hunger and malnutrition.

In Burkina Faso, with the support of the German Ministry of Food and Agriculture, the Food and Agriculture Organization (FAO) implemented the Education for Effective Nutrition in Action (ENACT) project, which developed a professional training course in nutrition education for undergraduate students. In 2015–2016, a pilot course was developed in collaboration with local universities; evaluation of this course showed that 95% of students adopted better eating habits. The same online course was piloted in Egypt by Senghor University (Dia *et al.*, 2017). These experiences show that training in nutrition education can be integrated into agriculture courses already available in local universities. Implementation of such courses will strengthen local capacity in planning, implementing, and evaluation in nutrition education among students at the undergraduate level.

Apart from traditional training on nutrition at universities, regional colleges, and secondary schools, education through online sources has also increased over time. Massive open online courses (MOOC) provide learning opportunities to over 12 million students worldwide. These include 60,000 students from India, 60,000 students from other Asian countries, 33,000 students from African countries and 32,000 students from Latin American countries. These types of courses are popular among developing-country students because they are easily accessible, relatively cheap compared with university-level courses, and flexible. Many of the courses offered on MOOC focus on food and nutrition (Geissler, 2015). Such courses can be used to strengthen capacity and provide training to current or mid-level extension agents.

Integrating Nutrition into Agricultural Extension

Approaches that improve the content and delivery of knowledge on agriculture–nutrition linkages, such as EAS, also have the potential to make strides in the field (Davis *et al.*, 2014). Sigman *et al.* (2014) assessed agricultural extension, nutrition education, and integrated agriculture–nutrition extension services in Malawi. The review showed that some progress had been made: the system relied on stakeholder panels to articulate farmers' needs and demands to the Department of Agricultural Extension; and made use of farmer and model villages, community volunteers to promote nutrition at the household level, and a 'positive deviance' program that identifies beneficial nutrition practices used by mothers of well nourished children from poor families. However, challenges remain, including a lack of program capacity, infrastructure and budget, program quality, and coordination and harmonization. Similar results were presented by USAID (2014), which reviewed three Feed the Future Activities in Ethiopia.

Some approaches have focused on direct training of extension agents. In 2011, the government of Malawi initiated the Improving Food Security, Nutrition Policies and Program Outreach project with the aim of improving agriculture–nutrition linkages by enhancing the capacity of rural extension agents. Extension agents facilitated community-based demonstrations, teaching participating households new recipes and preparation techniques. The evaluation of this project concluded that households improved their diets by consuming locally available foods (Fanzo *et al.*, 2013).

Farmer field schools (FFS) have traditionally been used to reach farmers with information and support on agricultural production and productivity. Some countries have begun experimenting with integrating nutrition content into this model, with varying degrees of success. Senegal has been implementing FFS since 2001. In 2015, FAO conducted a survey to assess nutrition knowledge among farmers who are a part of the FFS in the Niayes area. Results of this survey showed that 90% of the farmers did not have a basic understanding of nutrition. In response, FAO initiated the Promoting Healthy and Sustainable Agriculture project in four large agroecological zones of Senegal. After 5 months of attending this nutrition-sensitivity FFS, participants exhibited a significant increase in their understanding of nutrition and balanced diets, when compared with the baseline survey. Further, the dietary diversity and meal frequency among children of participants also improved (Dia *et al.*, 2017). Bangladesh also used an FFS program led by facilitators from local non-governmental organizations (NGOs) contracted by Strengthening Partnerships, Results, and Innovations in Nutrition to target pregnant and lactating women (Fanzo *et al.*, 2013). Kuria (2014) analyzed the effectiveness of FFS in eastern Africa. Currently, facilitator trainings include minimal nutrition content and primarily focus on increasing agriculture production. Other areas such as food utilization, preservation, storage, consumption, and preparation are completely neglected. For example, participants in this study were encouraged to consume food produced in their kitchen gardens, farms, or households. However, they lacked knowledge of the nutritional content of the food they were producing, thus resulting in a disconnect between agriculture production and nutrition outcomes.

Recent research has also delved deeply into the content of EAS materials and trainings.

For example, Dia *et al.* (2017) analyzed the integration of nutrition in peer-reviewed EAS materials in Africa. They looked at material focusing on horticulture and crops, livestock and fisheries, food processing, fortification and storage, hygiene, consumers, and gender sensitivity. According to the study, while public universities in Africa initially limited transferring information to farmers, access to knowledge within the past decade has become more decentralized and pluralistic. Nevertheless, the authors found that ineffective training received by extension agents limited their ability to provide nutrition-sensitive agricultural extension.

Fanzo *et al.* (2015b) examined the integration of nutrition content into current EAS around the world. The study showed that efforts to increase the availability of nutritious food was the most common integration of nutrition into EAS. These efforts focused on home gardening, the production of nutrient-dense foods, biofortification, and the reduction of post-harvest losses to preserve nutritional value (by controlling aflatoxin). However, the training received by extension agents was mostly inadequate and focused primarily on technical agricultural skills (Fanzo *et al.*, 2015b).

Apart from traditional extension delivery techniques, new methods such as using media to deliver extension services can successfully integrate nutrition into the current extension messages delivered to farmers, often at a low cost. Kadiyala *et al.* (2014) examined the feasibility of delivering maternal, infant, and young child nutrition information to nutritionally vulnerable groups in rural India through informational videos containing behavior change communication. Ten videos focusing on maternal, infant, and young children nutrition were included and disseminated in 30 villages in India. They found that the nutrition messages were well received by the villages, highlighting the potential of this approach to improve understanding of agriculture–nutrition linkages among rural populations.

To effectively integrate nutrition in the agriculture extension and advisory services provided, there is a need to engage communities, create demand for nutrition, and improve channels of communication (Fanzo *et al.*, 2015b). For example, in Kenya, the government has made an effort to shift toward more participatory and demand-driven EAS to increase farmer participation and use exhibitions, shows, and farm visits to generate awareness of nutrition (Fanzo *et al.* 2015b).

Capacity for Policy Research

Since policies and programs implemented within the agriculture sector have direct or indirect impacts on nutrition and human health (Hawkes, 2007), it is crucial to design and implement programs and policies that are complementary to both sectors. Food policy research plays a significant role in guiding and improving design and implementation of agriculture and nutrition policies. Despite the global increase in agriculture research spending and capacity since 2000, some countries significantly lag behind due to a lack of qualified researchers to generate food policy research (IFPRI, 2017). A country's capacity to perform food policy research and analysis is determined by its ability to develop, design, and implement evidence-based policies. Babu and Dorosh (2013) surveyed 30 countries to measure the individual, organizational, and system capacity to undertake food and agriculture policy research. They developed a food policy-related index of measures of human capacity, human capacity productivity, and strengthening of institutions. To perform food policy research and implement evidence-based policies and programs, collecting timely and reliable data is crucial. Data collection and analysis remains a challenge for many developing countries. As a consequence of this capacity gap, limited evidence is generated and monitoring and evaluation (M&E) efforts are inconsistent in countries. This can lead to a country's inability to generate context-specific solutions locally rather than depending on external donor organizations.

Ensuring that nutrition-sensitive policies and programs are backed up by academic research can also help bridge the gap between agriculture and nutrition in both theory and practice. For example, the Evidence-informed Decision-making for Nutrition and Health (EVIDENT) initiative, established as an international North–South partnership in 2014, aims to enhance the leadership capacity of African researchers, improve knowledge management, and provide high-quality methodical training and support to decision-makers involved in nutrition. EVIDENT has developed specialized training courses on systematic review techniques and had trained more than 60 stakeholders and researchers as of September 2016. It also developed guidelines on evidence-informed decision-making that will be used for pilot studies in Benin, Ethiopia, Ghana, and South Africa (Holdsworth *et al.*, 2016). Other initiatives that seek to advance evidence-based nutrition-sensitive decision-making include Agriculture for Nutrition and Health (A4NH), the African Evidence Network, Building Capacity to Use Research Evidence (BCURE), Leveraging Agriculture for Nutrition in South Asia (LANSA) and Leveraging Agriculture for Nutrition in East Africa (LANEA), Supporting the Use of Research Evidence (SURE), the SECURE Health Programme, and VakaYiko Consortium (Holdsworth *et al.*, 2016).

Lessons Learned

Despite an increased awareness that policies and programs designed and implemented in one sector, such as agriculture, have implications for other sectors, such as nutrition and health (Fan *et al.*, 2012), cooperation among these sectors in designing and implementing programs and policies that complement and reinforce their goals remain weak (Babu, 2011). In order to address challenges faced, the capacity to understand multisectoral approaches is the first step. However, efforts to develop such multi-disciplinary capacity remain limited (HLPE, 2017).

To address malnutrition, the application of knowledge from different disciplines is crucial. Multisectoral engagement such as including courses from different disciplines (agriculture, food systems, environment, climate change, etc.) in formal education focusing on nutrition and vice versa should be encouraged (Laar *et al.*, 2017). This integration of courses will ensure that graduating students have the necessary skills and both theoretical and practical knowledge of the impacts of agriculture on nutrition (Fanzo *et al.*, 2015a).

To be able to scale up the various initiatives highlighted in this chapter, a system-level approach is necessary. But system-level approaches require an enabling environment for nutrition-sensitive agriculture. Van den Bold *et al.* (2015) provided stakeholders' perspectives from three South Asian countries (India, Bangladesh, and Pakistan) to understand if there is an enabling environment for nutrition-sensitive agriculture in South Asia. Their results showed that all three countries lacked an understanding about agriculture–nutrition linkages at all administrative levels. Other capacity issues included lack of investment in nutrition training for community-level workers, limited access to information and technology of subsistence farmers, limited capacity of researchers, and lack of coordination among stakeholders. Further, the capacity of researchers also seemed to be deteriorating in some countries due to a brain drain and employment of under-qualified personnel. Similar results were seen for three East African countries: Ethiopia, Kenya, and Uganda (Hodge *et al.*, 2015).

Insufficient human resource capacity has also been considered a significant constraint in improving nutrition-sensitive agriculture, especially in South Asia (Gillespie *et al.*, 2015). In both East Africa and South Asia, efforts to cultivate and strengthen leadership and capacities at different levels have suffered from inadequate funding (Gillespie *et al.*, 2015) and policy-makers' inability to understand and implement evidence-based policies. Indeed, lack of funding has been recognized as a major system-level challenge to incorporate nutrition into many extension and advisory services around the world (Fanzo *et al.*, 2015b).

Conclusion

Despite increased recognition of the impact of agriculture on nutrition outcomes, linkages between these sectors remain weak. This gap in cooperation can be partially explained by limited capacity at the individual, institutional, and system levels. This chapter has focused on just two facets of individual and institutional capacity: multi-disciplinary education and extension and agricultural services, the lack of which have seriously hampered coverage, impact, and sustainability of nutrition programs (Shrimpton *et al.* 2016; HLPE, 2017).

But capacity needs are wide and varied. At the individual level, they include technical skills for data collection, data analysis, and advising on investments and policies. This type of training needs to be provided within multisectoral teams to fully align program and policy developers and implementers (Jerling *et al*., 2016; HLPE, 2017; Laar *et al*., 2017). Capacity at the institutional and system levels also needs to be strengthened. At the institutional level, strengthening capacity to improve communication and sharing research findings among different ministries, intergovernmental organizations, the private sector, and farmers is critical. Consistent efforts to use M&E systems and tools to ensure accountability and tracking progress of programs are needed. Finally, capacity is needed at the system level to improve global-level coordination in the development and implementation of policies and scaled-up initiatives that can start to accelerate progress against hunger and malnutrition.

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A researcher uses a handheld GPS device in Colombia. The instrument will help researchers collect and aggregate data on the planting decisions of hundreds of the country's fruit farmers. (Neil Palmer/CIAT)

14

Big Data in Agriculture and Nutrition

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Why Do Agriculture and Nutrition Need Big Data?

The earth provides humans with enough resources to feed our growing population, yet 815 million people live with chronic hunger. Although human health has generally improved, the current food system faces many challenges, including undernutrition, micronutrient malnutrition, and rising rates of obesity (FAO, 2018).

The amount of data collected on global food systems is immense, and the Sustainable Development Goals (SDGs) of the United Nations (UN) (especially SDGs 2, 3 and 17) encourage the sharing of information and data on agriculture and nutrition. Despite this call to action, many stakeholders, from farmers to governments, lack actionable data-driven insights and a clear understanding about how data translate into action. There are still many knowledge gaps on linkages among agriculture, nutrition, and the food system, especially complex systemic issues throughout the value chain. The power of data to begin closing these gaps remains largely untapped.

The food system community sees a huge potential for big data in agriculture to lift farmers out of poverty (Patel, 2013), and ensure that parents can feed their children nutritious, diverse foods (Lung'aho, 2018). In the USA, venture capitalists spent US$3 billion on 'agtech' (digital technology in agriculture) in 2016, with 46% of investors focusing on big data and analytics (Walker *et al.*, 2016). Large data initiatives such as the CGIAR's Big Data in Agriculture Platform have made thousands of datasets and publications available (Pineda, 2018). In order to establish a global data ecosystem that yields powerful insights and recommendations on the ways in which agriculture can improve nutrition, the community must ensure that the benefits of big data are for the betterment of all and not only for the few.

What Is Big Data?

Is big data a trend hyped by the media, or does it indeed have the power to 'disrupt' agriculture systems for the benefit of nutrition? Like many terms within agriculture, nutrition, and sustainable development such as 'food security' (Gibson, 2012), and 'food system' (e.g. Edgar and Brown, 2013), 'big data' lacks a universally agreed definition (Bhadani and Jothimani, 2016).

The overarching characteristics of big data that apply to most disciplines are the 3Vs: Volume, Velocity, and Variety, with a fourth V, Veracity, also applicable to agriculture and nutrition.

- **Volume:** how much data are collected. Volume depends on the amount over time, which informs the next component (Bhadani and Jothimani, 2016).
- **Velocity:** how fast data are collected. In agriculture and nutrition, an oft-mentioned benefit of big data is the opportunity for near-real-time analysis and decision-making. For example, early warning systems provide real-time data on agricultural production, weather patterns, nutritional status, and other factors and send alerts to policy-makers on emerging humanitarian crises.
- **Variety:** what types of data are collected. Variety of data is one component that makes big data especially applicable to agriculture and nutrition. With the onset of digital data collection, the internet, and smartphones, big data has changed what data 'look like'. Instead of numbers on crop yields or stunting rates in a spreadsheet, data also include maps and GPS coordinates, photos (of eating habits, for example), texts (nutrition messaging), relationships (mapping of agriculture–nutrition stakeholders, for instance) and many more (Sonka, 2014).
- **Veracity:** how reliable is the data source. Good data quality is essential for optimal decision making, especially when one decision can impact the nutritional status or livelihoods of a large segment of a population (Gandomi and Haider, 2015).

It is important to consider that big data fulfills a specific role within the larger data ecosystem. The data ecosystem includes all sizes and types of datasets. Data may not become big data unless they are analyzed at a certain scale. Importance and impact of the dataset may not be correlated with the dataset size.

What Does Big Data Look Like in Agriculture and Nutrition?

Data are collected from a variety of sources and in many ways, which is why applications of big data can be applied in so many ways across the food system. As mentioned earlier, in order for data to be 'big', there must be a large amount, collected quickly, that takes a wide variety of forms. There are many datasets within agriculture and nutrition that fulfill these criteria, as listed in Table 14.1.

Table 14.1. Types of data in agriculture and nutrition (scale will determine whether or not they are big data).

Data type	Sub-type	Definition	Sources
Remote sensing		The collection of information from a distance	NOAA, 2018
	In situ (subsurface) sensors	Small scale, stationary, attached to the earth, such as weather stations or water quality sensors *Example*: Satellites use weather stations to validate and enrich data sources to provide accurate, real-time information to farmers	Kotamäki *et al*., 2009
	Aerial, non-satellite	Medium scale, sensors on aircraft, such as Unmanned Aerial Vehicles (UAV), drones *Example:* A company called Agribotix is developing drones with sophisticated multispectral sensors and programs that detect pests and diseases and deliver quick targeted solutions automatically	Clause *et al*., 2018 King, 2017
	Satellite	Large scale, sensors on satellites *Example:* The company Planet images the Earth every day, collecting 1.4 million 29MP images per day, covering more than 300 million km^2. Over 6 terabytes per day are sent back to earth *Example:* The European Space Agency's Copernicus satellites collect atmospheric and climate data open for public use. The data inform programs like APOLLO, which provides advisory services for small farms	Clause *et al*., 2018 Planet, 2017 Copernicus, 2018
Farm equipment and robotics		Farm equipment equipped with GPS, guidance systems, crop-specific sensors, for planning, monitoring, analysis and planning. Also called, 'smart farming' and 'precision agriculture' *Example:* Powerful algorithms allow robots to use the RGB spectrum to pick strawberries precisely at peak nutritional value. Big data is used to power the algorithm, and every strawberry picked becomes a data point in a big dataset *Example:* A small autonomous robot called Bonirob can analyze soil samples to map pH and phosphorus concentrations in real time, helping to improve soil health	Killpack, 2011 Wolfert *et al*., 2017 King, 2017
Mobile phones through social media and crowd-sourcing		Mobile phones have allowed for collection and dissemination of information on a very large scale *Example:* Mobile phones allow smallholder farmers to share to information and receive alerts and recommendations around planting and selling	USAID, 2013 Noronha *et al*., 2011

Continued

Table 14.1. Continued.

Data type	Sub-type	Definition	Sources
		Example: Fitness and diet tracking applications allow companies to observe eating habits of a population on a wide scale. Apps like Twitter and Facebook (which also owns Instagram and WhatsApp) can view their users' messages, photographs, and behavioral trends, such as eating habits	
Omics		The basis of human health, nutrition and disease knowledge, and is also applied to agricultural science through pest and disease resistance, and nutritional value of crops *Example:* Personalized medicine and personalized diets can be developed from omics big data generated by universities, industry, combined with an individual's personal health data, either from their hospital's health records or the health apps attached to mobile phones (Apple HealthKit, Samsung S-Health) and wearables (Fitbit, Apple Watch)	Alyass *et al*., 2015 Van Emon, 2016 Kraft, 2017
Research		Any type of research data collected by industry, government, or academia, including market research collected by private-sector companies on trade, marketing, wholesaling, retailing, and online sales	

While big data can be sourced from industry, academia, and government, it can also be generated by the users of farm equipment, mobile phones, and social media. When people use an app, the information they input and their behavior while using the app then becomes big data for others to interpret and use. As the number of mobile phones and smartphones increases, the data that is generated also increases. Although it is difficult to find examples of user-generated big data for nutrition, apps such MyFitnessPal and other diet trackers may provide examples in the future.

Two of the biggest challenges for farmers are risks from external stresses and a lack of a safety net. Early-warning systems and insurance help farmers overcome these risks, especially in the age of climate change. The use of big data is allowing for better early warning systems and insurance schemes than ever before, using a combination of data types. Initiatives such as the Famine Early Warning System Network (FEWS NET) can drastically improve evidence-based analysis for decision-making in the most vulnerable places. FEWS NET was established in 1985 and, using big data from satellites and research, it can publish reports and maps of food insecurity projections, as well as crisis alerts and specific data on weather, markets, and nutrition, allowing governments to help citizens in a timely way (FEWS NET, 2018). The impact of FEWS NET could be better assessed if research were collected on how governments used the early warning system and how lives of the affected people were improved.

Big data can also help with insurance and access to credit with a combination of big data types. India-based company Satsure analyzes satellite data, market data, and weather data using machine learning and big data analytics to ensure that farmers in India who have suffered crop losses due to climatic shocks receive compensation quickly. Satsure is a relatively new company and evaluations of its program are forthcoming (e-Agriculture, 2017).

From Data to Decision

All types of big data must go through a series of steps, in combination with other types of data,

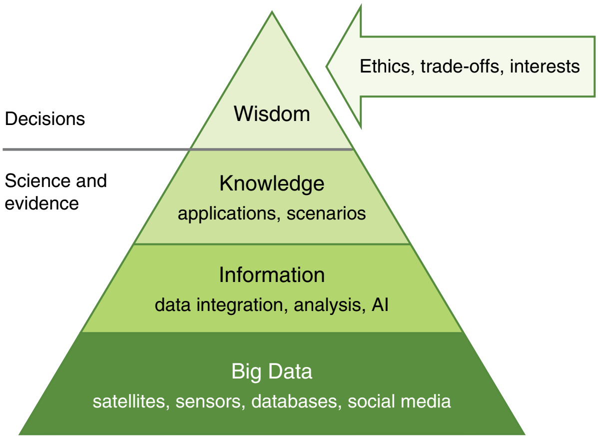

Fig. 14.1. DIKW hierarchy, from big data to decision-making for societal challenges (adapted from Lokers *et al.*, 2016).

with a variety of stakeholders in order to make a data-driven decision. Figure 14.1 shows this potential pathway.

Big data from the sources mentioned above will contribute to the development of an evidence base. Data must be analyzed by companies or individuals who have developed tools to do so, and after analysis several options will be presented for certain scenarios and applications. Big data may also be used to create software to predict and quickly determine where a problem is happening and tell the user the best way to overcome it. In order for that software to be written, large amounts of data are needed to support the recommendations (Lokers *et al.*, 2016). It is only after this step that decision makers have the knowledge to make a decision. Their own ethical position, interests, and interpretation of potential trade-offs will in turn influence the final result.

Challenges in Big Data in Agriculture and Nutrition

Several challenges must be overcome in order for big data in agriculture and nutrition to help stakeholders make optimal decisions.

Technological challenges

By definition, 'big data' is very large and complex data, often requiring high-end, extensive (and costly) technology for management and analysis. Food systems research is increasingly interdisciplinary, which makes data management a more complex challenge than other domains. Each discipline will have different targeted objectives, data formats, schemas, vocabularies, standards, and granularities (Lokers, 2015).

As more data are gathered on agriculture and nutrition, the 3Vs of big data – volume, velocity, and variety – will increase exponentially. In order to make best use of the data, large investments will be needed to store and preserve the data on platforms and in databases. Time, effort, and money to spend on data management technology are currently minimal across relevant stakeholders (Shekhar *et al.*, 2017).

Data are collected in different ways, in different formats, using different technologies and in different languages. For big data to be most effective, different data should be able to be layered on top of each other, with each layer helping to further inform a solution or decision. This layering is referred to as 'data integration' with the data needing to be 'interoperable' for data integration to occur. Data integration can be fairly easy if the data sources are interoperable, as XML, APIs or text files (Kadadi *et al.*, 2014), but if they are not, or the semantics and vocabularies do not match, data integration may be difficult, expensive, or impossible.

Institutional challenges

Arguably, high data quality supersedes any other analysis or integration issue, as the costs of bad-quality data may be greater than having no data at all (Cai and Zhu, 2015). High data quality is also essential for building trust in data sharing (Allemang and Teegarden, 2016). Quality assurance standards are not common in agriculture and nutrition data collection or management. However, it is also difficult to know 'how good is good enough?' Progress is being made in this area (Grassini *et al*., 2015; Lu *et al*., 2015).

For almost all stakeholders, institutional data management is an afterthought. It is usually not integrated into the research design or collected with the intent to share or reuse it. Money is not allocated for quality assurance, curation, and sustainability. Depending on the research project, the volume, velocity, and variety of data may make retroactive data management difficult (Smith *et al*., 2017; Adrian *et al*., 2018; Roett, 2018).

Cultural challenges

The standard operating procedure of business, science, and management is closed data, meaning data that are not open or shared (ODI, 2015). If big data is to be used optimally, organizations need to share or open their data. However, this process may require them to change their business models, the people they hire, their business relationships, and their institutional culture. Such a process is slow and potentially threatening to risk-averse organizations, or those that do not have the financial or human capacity to change. Researchers in universities are especially averse to opening and sharing data, for fear of others stealing their results. However, they are open to reusing data that others have published (Digital Science, 2017). Other cultural considerations include bureaucracy and other social structures that impede data sharing, norms and structures that can be highly variable across countries or regions.

Ethical challenges

Data ownership rights are usually absent in legal frameworks over the handling of agriculture and nutrition data. More often, data are owned by the person or organization that collects them (or the one that funds their collection) due to a proprietary interest in the data being collected, instead of the person that the data is about. This can lead to privacy and security issues, along with the emergence of a digital divide, meaning that big data is helping powerful entities, instead of improving livelihoods of the disadvantaged. Most smallholder farmers are not able to understand, interpret, and use the analysis of data without intermediation. With the increase of smartphones, GPS on tractors, wearable technology or devices, and personally identifiable information, these ethical challenges are crucial to overcome (de Beer, 2016; Kshetri, 2014).

An example of this ethical challenge can be seen within the context of the operating practices of firms that manufacture tractors and heavy agricultural tools. One such manufacturer, John Deere, has made tremendous advances in precision farming using crowd-sourcing and remote sensing in the USA. The company tracks its agricultural machinery on each farm and aggregates it to improve predictions and provide recommendations, usually to promote its own products. However, since John Deere also owns the data that its machines generate, farmers cannot see the data being sent to John Deere unless they buy it back. Some farmers believe that they should own the data and be compensated if John Deere uses it to make business decisions (Woodard *et al*., 2017). In a survey performed by Farm Industry News, farmers expressed a desire to be in control of their data and were concerned about how their data may be used (Farm Industry News, 2016).

Lessons Learned and Solutions Towards Putting Big Data to Use in Agriculture and Nutrition

Recent research and current initiatives are leveraging the potential of big data to help solve large problems in agriculture and nutrition (Kshetri, 2014), though not enough time has yet passed to see genuine, sustained benefits. However, big data's momentum is forcing a wide range of stakeholders to learn from one another to develop innovative and novel solutions to the challenges listed above.

Internet of Things (IoT)

The Internet of Things (IoT) has a huge potential to connect agriculture and nutrition data, providing insights on how nutrition can be retained along the food value chain. The IoT aims to interconnect objects such as mobile phones, tractors, *in situ* sensors, and wearables using wireless sensors, radio frequency identification (RFID), and other web-based capabilities, and tackles the data integration challenge. From the agricultural production angle, the IoT would provide the tools to better monitor agricultural production by providing a smarter understanding of farming conditions, rainfall, pest and disease threats, and best management practices. It lays the groundwork for high-tech, remote-controlled farm logistics and processing, such as robots for weeding and precise fertilizer application. The IoT would then link production to logistics by remotely monitoring ambient conditions during transportation, positively impacting food quality and traceability. Subsequently, the IoT could combine the results of the IoT chain with personalized health through wearables, omics data, mobile phone apps, and documented nutritional data from healthcare providers, documenting the link between production and nutritional status (Sundmaeker *et al.*, 2016). Data must be interoperable for a successful IoT to develop.

Open data

Data should drive all important decisions in agriculture and nutrition, big or small (see Fig. 14.1). Open data is data that anyone can access, use, or share (ODI, 2018) and is potentially the most impactful way that big data can make a difference in agriculture and nutrition. In addition to fast and effective decision making, open data can drive innovation that everyone can benefit from, and can promote organizational and sector change through transparency (Carolan *et al.*, 2015). Agriculture and nutrition are highly interdisciplinary, and open data will allow stakeholders to more easily access and use data from previously inaccessible disciplines. Research and support behind open data is strong (Allemang and Teegarden, 2016), but there are knowledge gaps, in terms of clear examples of how opening data can explicitly overcome development challenges.

In order to maintain the high quality of open data, standards are needed. These provide guidelines on how to collect, manage, and integrate data and include common semantics and ontologies (Pesce *et al.*, 2018). One such standard is the FAIR Principles (**F**indable, **A**ccessible, **I**nteroperable, and **R**eusable), which are becoming more well known and accepted among researchers, governments, and other stakeholders. 'Findable' means that data can be found and curated; 'accessible' means that the data are usually in machine-readable code, or easily processed by a computer such as through XML or CSV; 'interoperability' allows data to be manipulated and aggregated with data from elsewhere to produce results that are of practical use; and 'reusable' means that the dataset should be openly licensed (Wilkinson *et al.*, 2016). Licensing provides guidelines on how the data can be reused. Most open datasets use the Creative Commons licensing system (Creative Commons, 2018).

The community using the FAIR Principles is growing and includes donors, universities, and governments, including the European Commission (EC) (DTL, 2016). The EC has developed 'Guidelines on FAIR Data Management in Horizon 2020' (European Commission, 2016) which mandates that all data from its Horizon 2020 projects, including those on food security, are open by default and adhere to the FAIR principles.

Collaborative platforms for big and open data

Organizations have learned that the speed of innovation depends on collaboration and mutual support. Several new initiatives are helping the food-system community collaborate and convene around the big data challenges and solutions.

The Big Data in Agriculture Platform is an initiative launched by CGIAR in 2017. The platform was created to overcome the challenge of big data management and the transformation of information into action. Its vision is to: organize existing data; improve data management, data generation, and access across the 15 CGIAR centers; convene members of CGIAR and its partners to use big data to solve agriculture and nutrition issues; and inspire others to do the same. The platform aims to achieve this vision by 2022 (CGIAR, 2018). To date, 2000 datasets and 50,000 publications have been made available (Pineda, 2018).

The Global Open Data for Agriculture and Nutrition (GODAN) initiative is a global network of over 850 (as of November 2018) partner organizations from all sectors, who advocate for open data and work together to overcome challenges, especially as they relate to food security. GODAN encourages all partners to open up key datasets, and to create policies for sustainable data sharing. The GODAN Partner Network includes organizations from all stages of the food system who have the opportunity to collaborate and see how their data can help others in the community. A primary goal of GODAN is trust-building and responsible open data management among partners (GODAN, 2018).

What Can Stakeholders Do to Make Big Data Work for Agriculture and Nutrition?

All stakeholders

Big data, when analyzed and layered together with other datasets within the data ecosystem, may help stakeholders in agriculture and nutrition to make better decisions across the entire food system. Although there are actions specific stakeholders can take towards making big data work for agriculture and nutrition, some actions are universal.

Collaboration

As in the example above of IoT, stakeholders from all sectors need to collaborate, share data, and co-strategize towards a common goal. For big data to have sustainable benefits for everyone, the key is cooperation and collaboration.

Responsible data use

A plethora of research exists on why data ownership and responsibility are important in big and open data in agriculture and nutrition (Kshetri, 2014; Bronson and Knezevic, 2016; Carbonell, 2016). If data are to be published and used responsibly to prevent power imbalances, empower vulnerable communities, and promote sustainable agriculture and nutrition (Ferris and Rahman, 2016), policies around clear privacy, security, and ownership principles must be drafted and consistently updated (de Beer, 2016); data subjects must be educated on how the data about them will be used and how they are compensated; and the rights of vulnerable people, especially smallholder farmers, must be protected.

Although the development community might broadly support these principles, there are as of yet few examples of its adherence in on-the-ground applications. Resources such as 'The Data Ethics Canvas' (ODI, 2017) can help ensure that responsible data use principles are followed.

Policies

Big data management, technology, and decision-making processes are relatively new, and policies are the best way to ensure that different sectors, regions, and disciplines have a joint understanding of the issues, cooperate on potential solutions, and produce common standards. Resources such as 'Writing a Good (Open) Data Policy' (ODI, 2016) exist for policy support across all sectors. Sector-specific policy suggestions and progress are given below.

Governments

Most governments across the world have ministries of agriculture, food, and health that collect and organize a tremendous amount of data. Governments are often the stewards of the data that they collect (Smith and Jellema, 2016), can own the data, and host it. Much of the data that exist across the world collected by governments may not be considered big data, especially within developing countries. However, governments have a responsibility to interpret big data and act upon it for the benefit of their citizens.

Governments can facilitate the information flows between their ministries and ensure high quality data by continuously cleaning, curating, and updating government data, as well as publishing open data on the web when appropriate. They can: (i) reinforce the national technical infrastructure so that the open data can be accessed easily and reliably at all times by other stakeholders; (ii) build the capacity among stakeholders to use big (and open) data sources; (iii) financially support stakeholders that want to build information services for the agricultural and nutrition sectors based on open data sources; (iv) encourage business development for sustaining the information services being developed; and (v) stimulate other stakeholders (e.g. private sector, international organizations, NGOs, researchers) to publish their own data sources (GODAN, 2018).

Several governments are making progress on big data and open data. In 2017, the Ministry of Agriculture in Kenya, for example, signed the Nairobi Declaration along with nine other African ministers, a public commitment to work jointly on open data in agriculture and nutrition and data-driven decision-making (GODAN, 2017).

Research organizations and universities

Research organizations and universities generate big data, but historically researchers are driven to publish articles in peer-reviewed journals, instead of releasing high-quality datasets. This mentality is beginning to shift, with researchers increasingly expressing interest in publishing datasets, as long as they are attributed and receive a citation. The main drive behind this interest is universities incentivizing dataset publication as they start to consider its contribution to publication counts and increased likelihood of new donor funding (Digital Science, 2017).

Data ownership is a point of contention between universities and researchers. Universities believe that if research is conducted on their campus (regardless of funding support), they own the data. Researchers disagree and believe that they themselves own the data. Universities must clearly define data ownership by collaborating with faculty and researchers on ownership policies. They should also create the infrastructure, support, and resources for data best practice and management (Adrian *et al.*, 2018).

Donors

Donors spend billions of dollars on agriculture and nutrition research per year, funneled through universities, other governments, NGOs, and industry, all of which produce large amounts of data. Few donors fund the curation and maintenance of the high-quality data that results from their initial investments (Smith *et al.*, 2017). Universities and research institutions, in turn, follow the data policies of their project funders. However, donors are only recently recognizing that although they may have data management policies (such as open data or open access), grantees often do not have the resources or knowledge to comply fully with them.

Donors can best support their grantees through a combination of compliance and incentives. They can regularly monitor compliance and articulate clear expectations regarding budget allocations to ensure good data management (Smith *et al.*, 2017).

Industry

Each step within the food system (inputs, production, harvest, transport, storage, processing, retailing, consumption, and waste) has industry data collectors and users.

Publishers of academic research, such as Elsevier and Springer Nature (Springer Nature, 2016), are also industry stakeholders as they provide the primary throughput of scientific information that would lead to knowledge and decisions. Publishers can decide their own open data and open access policies, and pricing scales, to which researchers must adhere.

Business models for big data are well defined, but less so for big and open data. Companies such as Syngenta have found ways to publish open data for transparency and accountability. Syngenta's Good Growth Plan outlines six commitments for agricultural sustainability and has published the data for most of these components, including crop productivity, smallholder outreach, soil maintenance practices, biodiversity practices, and workplace safety. Syngenta found more value in making data open in promoting its social responsibility agenda than it would have in keeping the data closed (Allemang and Teegarden, 2016). Agribusiness may have the biggest challenge to address around data ethics policy, to ensure that farmers are not exploited for their data (Carbonell, 2016). More research and efforts are needed on development of sustainable business models for big open data in food systems.

In addition to business models, industry can adopt a view of data as a raw material to ascertain value for the company. The data value chain perspective can help companies use and reuse data to maximize analytics and tools for solving development problems and scaling up solutions (Dunhill, 2014). The research behind data value chains from IBM is solid, but is not yet applied in situational contexts.

Looking Ahead

As the international community works to fulfill the SDGs, big data will drive many of the efforts tied to linking agriculture and nutrition and reshaping the global food system. The collection of high-quality data is not sufficient. This vast well of information must translate into knowledge that is easily accessible by non-technical audiences, including policy-makers and civil society. By carefully building a system for open and big data, one that includes clear definitions, rules over ownership and use, and transparency and accountability, we can ensure that the benefits of big data are passed on to the most vulnerable segments of society.

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A man sells fruit from a boat in Bangladesh. Rice remains central to the country's agriculture sector and comprises the majority of what people consume. However, many Bangladeshis are slowly beginning to diversify their diets. (David Brewer)

15

Diversifying Rice-centric Agriculture and Diets: the Bangladesh Experience

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Background

Bangladesh has made great progress in feeding a large population with domestic agricultural production, despite facing declining arable agricultural land in an area smaller than 150,000 km^2. In the early 1970s, it was a food-deficit country with a population of about 75 million. Today, with a population exceeding 160 million, the country is self-sufficient in rice production, which has tripled during the past three decades. Seed, fertilizer, and irrigation, all known as 'Green Revolution technologies', have played a major role in the growth of rice production in Bangladesh.

Bangladesh's pace of economic growth has also accelerated in recent years, with real gross domestic product (GDP) growing at a rate of 6.5% percent on average per year in 2010–2016. In the fiscal year 2016–17, GDP growth reached 7.1%, the highest rate in the country's history. The incidence of poverty was also cut in half during the past 15 years, dropping from 48.9% in 2000 to 24.3% in 2016 (BBS, 2017). On the nutrition side, during the past two decades, Bangladesh recorded one of the fastest prolonged reductions in child stunting in the world – stunting dropped by 19 percentage points over 18 years, from 55% in 1997 to 36% in 2015 (NIPORT, 2015).

Despite these successes, the country faces big challenges. The Bangladeshi population suffers from sub-optimal maternal, newborn, and child health and survival outcomes. Approximately 19% of ever-married women between the ages of 15 and 49 and up to 31% of adolescent girls (15–19 years old) are undernourished (NIPORT, 2015). More than one-fourth of non-pregnant and non-lactating women are anemic, and 42–57% suffer from zinc or iodine deficiencies (ICDDRB *et al.*, 2013). In 2015, 55% of pregnant women were anemic (NNS, 2017).

These nutrition challenges are compounded by other downward trends. The country's pace of poverty reduction has recently stagnated. The national poverty rate fell by 1.2 percentage points annually from 2010 to 2016 compared with 1.7 from 2005 to 2010 (World Bank, 2017). The recent slowdown in agricultural growth partly explains the deceleration in poverty reduction. In 2007–2011, agricultural GDP grew at a remarkably high rate of 4.7% per annum, but during the following 5 years (2012–2016), annual growth roughly halved to 2.4%. This decline is mainly due to a decreased growth rate in rice production, from 4.8% per year during 2007–2011 to only 0.7% during 2012–2016.

This chapter reviews recent policy developments in agriculture and nutrition in Bangladesh, and then draws upon household-level data to examine trends related to agricultural production, food consumption and nutrition, and women's empowerment. Using this evidence, the authors present a government-led experiment that is working towards filling critical knowledge and action gaps for promoting nutrition-sensitive agriculture. Bringing together this evidence, they conclude that identifying, developing, and supporting synergies among the agriculture, nutrition, and health sectors is critical for Bangladesh to improve food and nutrition security.

Recent Policy Developments

Government policies and strategies have begun to underscore the importance of strengthening the linkages between agriculture and nutrition. The Country Investment Plan (CIP) for Food Security and Agricultural Development provided the foundation for improving food security, agricultural development, and nutrition in the country in 2011. Thereafter, policies began to take a more inclusive approach. For example, the 2013 National Agriculture Policy emphasized diversifying crops and producing crops with greater nutritional value to meet the nutrition demands of the population. As of March 2018, the 2013 National Agriculture Policy is undergoing stakeholder consultation, which has significant policy reform potential for strengthening the linkages between agriculture, nutrition, and gender in the country. Key recommendations for the updated National Agriculture Policy include expansion of national programs for the production of nutritious and safe foods, greater inclusion of women in the agriculture sector, strengthening agricultural value chains, and facilitating private-sector involvement.

Similarly, Bangladesh has demonstrated its strong policy commitment to improve nutrition, as evidenced by its pledge at the Nutrition for Growth Summit in 2013, its engagement in the Scaling up Nutrition (SUN) movement, its National Nutrition Policy, the proposed strengthening of multisectoral coordination for nutrition in its 7th Five Year Plan (2016–2020), its National Strategy for Adolescent Health (2017–2030), and its nutrition-focused health sector program (Health Nutrition and Population Sector Program (HNPSP) Project for Bangladesh).

Bangladesh is well positioned to accelerate progress on agriculture and nutrition. While progress has been made in recent years in bringing together agriculture and nutrition in policy commitments, there remains a lack of policy coordination – both within and between ministries – which undercuts effective policy implementation. Given the multisector and multistakeholder nature of food security and nutrition, formal mechanisms for inter-sectoral collaboration must be prioritized (Ahmed *et al*., 2011).

Evidence of Linkages Among Agricultural Diversity, Dietary Diversity, and Nutritional Status

The relationships among agricultural diversity, dietary diversity, and nutrition are complex and multidimensional. A recent study mapped five pathways through which agricultural interventions can affect nutrition, including: (i) increased food availability for household consumption; (ii) increased income for accessing food; (iii) reductions in market prices; (iv) shifts in preferences; and (v) shifts in control of resources within households (Arimond *et al*., 2011). Research undertaken by the International Food Policy Research Institute (IFPRI) in Bangladesh shows that Bangladeshi women are key actors within the food system, and that their empowerment improves dietary diversity as well as household food security (Sraboni *et al*., 2014). However, women in Bangladesh are historically less empowered and, despite playing an important role in agricultural growth, face persistent obstacles and societal and economic constraints in reaping the full benefits of agricultural livelihoods. Thus, the diminished role of women weakens the links between agriculture and nutrition in Bangladesh. Evidence from other countries in South Asia also supports the link between women's empowerment, agriculture, and dietary diversity.

There is also increasing evidence that agricultural production diversity leads to household dietary diversity. Hossain *et al*. (2016) found that rural households in Bangladesh that combined crop and non-crop agricultural activities (for example, crop production and livestock raising) had more diverse diets. Another study revealed that vegetable technology targeted at women who owned small land holdings increased their empowerment and improved their children's nutritional status (Hallman *et al*., 2003).

There is also some evidence on the relationship between dietary diversity and child nutritional status. A review of Demographic and Health Surveys (DHS) from 11 countries concluded that diverse diets are sometimes positively associated with child nutritional status (Arimond and Ruel, 2004). Studies undertaken in Bangladesh and India also found that low levels of dietary diversity are linked with poor child nutrition outcomes, such as stunting, wasting, or underweight (Rah *et al*., 2010; Menon *et al*., 2015). However, the association between dietary diversity and child nutritional status is sometimes not present or weak. This may be because minimum dietary diversity, as an indicator, is not very sensitive to changes in child nutritional status (Jones *et al*., 2014).

These studies contribute to an evolving understanding of the complex relationships among gender, production diversity, and nutrition outcomes. The evidence base is gradually being strengthened through research in countries including but not limited to Bangladesh. Using household survey data from Nepal, for example, Malapit *et al*. (2013) investigated the impact of women's empowerment in agriculture and production diversity on dietary diversity and anthropometric outcomes of mothers and children. The study showed that agricultural production diversity is positively associated with mothers' dietary diversity and body mass index, dietary diversity for children under 2 years of age and predicts weight-for-age (WAZ), weight-for-height (WHZ), and height-for-age (HAZ) z-scores of children over 2 years of age.

A Rice-centric Agricultural Sector, with Implications for Nutrition

In 2011, IFPRI researchers designed the Bangladesh Integrated Household Survey (BIHS) – the most comprehensive, nationally representative rural household panel survey to date in the country. IFPRI collected unique data under the BIHS, including plot-level agricultural production and practices, dietary intake of all household members using 24-hour recall, height and weight of all household members, and women's empowerment using the Women's Empowerment in Agriculture Index, a survey-based index designed to measure the empowerment, agency, and inclusion of women in the agricultural sector in an effort to identify ways to overcome those obstacles and constraints. Two panel survey rounds of the BIHS have been conducted – the baseline in 2012 (BIHS, 2012) and midline in 2015 (BIHS, 2015) – which track the same set of rural households over time. Results in this section draw upon data from the BIHS and secondary data from various sources.

Today, Bangladesh's agriculture scenario still reflects the country's early thrust towards achieving rice self-sufficiency. In 2012, over one-half (51%) of all farmers grew only one crop: rice (Ahmed *et al.*, 2017) (Fig. 15.1).

IFPRI research reveals that rice is one of the least profitable crops grown in Bangladesh (Ahmed *et al.*, 2015). Why, then, do most farmers not diversify agricultural production? Year-to-year price fluctuations are much larger for non-rice crops than for rice, indicating relatively high levels of market-induced risks for production of non-rice crops. High-value crops, especially fruit and vegetables, have thin domestic markets owing to relatively low levels of demand for them due to widespread poverty and inadequate purchasing power. An increase in production causes a sharp decline in market prices.

Agricultural diversity and dietary diversity are closely linked. Nearly three-fourths of cropped land in Bangladesh is under rice cultivation, and subsequently about 71% of the total dietary energy intake comes exclusively from rice (Ahmed *et al.*, 2017). One of the most important causes of widespread malnutrition is the deficiency in the habitual diet in Bangladesh, with rice contributing most of the total dietary energy, and other foods contributing much less than required. Although rice is a good source of calories, it is not a good source of protein and essential micronutrients. Despite this, rice provides over one-half of total protein intake (57%), 62% of total zinc intake, and 44% of total iron intake. These statistics illustrate the dietary gaps that have largely developed as a result of Bangladesh's rice-centric agriculture sector.

Between 2012 and 2015, Bangladeshis did begin to increase their consumption of fruits, vegetables, legumes, and animal-source protein such as dairy and meat. However, the severity of dietary deficiencies is more apparent when the proportion of people who have not consumed specific food groups within the past week is analyzed (Fig. 15.2). Although the proportion of people who did not consume dairy within the past 7 days dropped from 65.2% to 47.4%, one-half of rural households are still completely deficient in dairy consumption. Similarly, the proportion of people who consumed fruits and vegetables grew tremendously between 2012 and 2015, but there is still more work to be done, with 29.3% and 23.0% of rural households not consuming any fruits and legumes during the preceding 1-week period in 2015.

One alternative for getting the most nutrition out of Bangladesh's monotonous diets is to fortify highly consumed crop varieties with micronutrients through biofortification (see Chapter 5). Rice is an excellent vehicle for biofortification

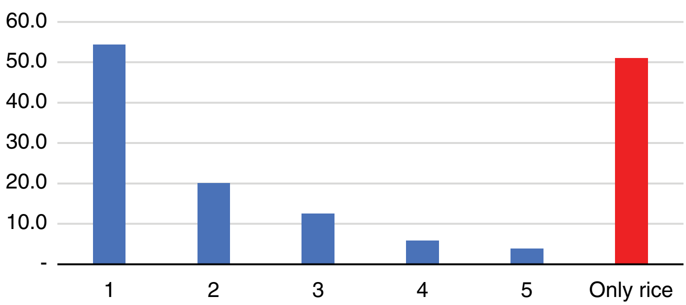

Fig. 15.1. Number of crops grown by farmers in Bangladesh (BIHS, 2012).

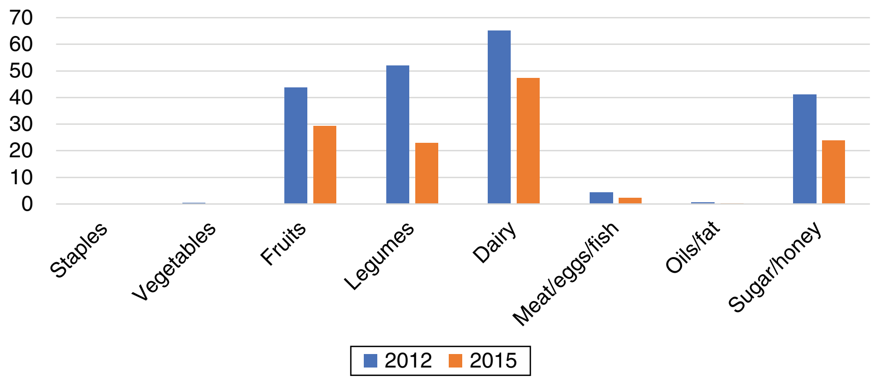

Fig. 15.2. Proportion of people who have not consumed specific food groups in past 7 days from 2012 to 2015 (BIHS, 2012, 2015; Ahmed, 2013).

(with iron and zinc) in the sense that the entire population eats it. Zinc-enriched rice can fight child mortality and stunting, namely by reducing diarrhea and pneumonia.

Recent agricultural research initiatives by HarvestPlus and the Bangladesh Rice Research Institute (BRRI) have made significant headway in research on biofortification. Bangladesh is the first country to develop a rice variety biologically fortified with zinc. Biofortified crops such as high-zinc rice and orange-fleshed sweet potato (OFSP) in Bangladesh have been efficacious in reducing zinc and vitamin A deficiencies. Up to 2016, HarvestPlus had reached nearly half a million farm households with approximately 908 t of seed consisting of four zinc rice varieties in 62 out of 64 districts (HarvestPlus, 2017). These varieties provide up to 60% of daily zinc needs, along with iron and vitamin A. By 2015, HarvestPlus had reached 160,000 households in Bangladesh with zinc rice and aimed to reach 1.4 million households by 2018 (HarvestPlus, 2017). Biofortified crops are one way in which agriculture is transforming to enhance nutrition outcomes in a rapidly growing population.

Another option is to diversify agriculture by way of utilizing contract farming, which can protect farmers from the price risks of producing other nutrient-dense crops. Under contract farming, the farmer provides agreed quantities of an agricultural product to an agribusiness firm, based on the quality standards and delivery requirements of the firm, usually at a price negotiated and established in advance. Agribusiness firms may also agree to support the farmers through input supply, credit, extension advice, and transporting produce to their premises (Eaton and Shepherd, 2001).

Despite its potential, very few contract farming models have been successfully adopted in Bangladesh. Notable exceptions include tobacco, with support from multinational companies like British American Tobacco; BRAC's crop and non-crop agricultural activities, which connect local producers with BRAC retailers around the country; and the poultry firm Aftab Bahumukhi Farm Limited (ABFL), which provides chicks, feed, veterinary supplies, management services, and transportation to producers in Kishoreganj District (Begum, 2005; Barket *et al*., 2008).

Strategies that balance the intensification of rice production and agricultural diversification should be prioritized, which may help meet the caloric and nutritional demands of the population, as well as improve farmers' incomes by cultivating more profitable, yet risky crops. Addressing the market efficiency issues is likely to be an effective means of reducing the risks associated with adoption of high-value agricultural production. Carefully designed research is needed to reveal the constraints to agricultural diversity and to formulate appropriate policies to remove them.

Trends in Non-crop Agricultural Production

Despite the centrality of rice to Bangladesh's agriculture sector, other subsectors of agricultural production have nevertheless been thriving. The growing dynamism of the livestock and fisheries subsectors in Bangladesh has great potential to advance food availability, nutrition, and income. While agricultural research often emphasizes crop production, recent studies show that nutritional status is more closely linked to the consumption of animal-based protein sources rich in micronutrients – from livestock and fish, for instance – compared with energy consumption. Therefore, the rise of livestock and fisheries holds promise for both the economic well-being and health of the country.

Aquaculture has experienced rapid growth during the past 30 years, amounting to a 25-fold increase in farmed fish production (Hernandez *et al.*, 2017). This boom has paved the way for major economic gains. When growth in the agriculture sector was faltering, fisheries was generating an average annual growth rate of 5.5% from 2007–2008 to 2013–2014 (FRSS, 2017). The fisheries share of value added in agricultural GDP reached 25% in 2013–2014. In 2014, Bangladesh was the fourth largest aquaculture producer globally, after China, India, and Vietnam (FAO, 2016). This private-led growth primarily benefited thousands of small actors along the fish value chain (Hernandez *et al.*, 2017).

The growth of fisheries has had positive impacts on food consumption and nutrition. Nearly all aquaculture production (94%) in Bangladesh is consumed domestically (Hernandez *et al.*, 2017). In particular, small indigenous fish are a rich source of animal protein, essential fats, iron, zinc, calcium, and vitamin A. Various studies have found that households in Bangladesh that are involved in aquaculture activities reap immense nutritional benefits and have lower levels of poverty (Murshed-e-Jahan *et al.*, 2010; Murshed-e-Jahan and Pemsi, 2011). Hallman *et al.* (2003) found that community-based fishpond technology in poor rural areas of Bangladesh contributed to higher shares of non-farm income and improved household nutrition. The rise of fisheries in the country has also prompted research on the relative nutrition of farmed fish versus non-farmed fish. Bogard *et al.* (2017) determined that non-farmed fish are much more effective at closing micronutrient gaps than farmed fish. As fisheries continue to be an important source of income and nutrition for urban and rural households in Bangladesh, research in this area will be critical in advocating for nutrition-sensitive aquaculture policies and programs.

The livestock sector is also an important source of livelihoods for many poor agricultural households in Bangladesh, as well as a source of protein, and vitamins and minerals within diets. Since the poor have relatively little access to land, high-value, labor-intensive enterprises, such as backyard livestock rearing for milk production, provide employment for poor and disadvantaged segments of the population, especially women (Ahmed, 2013). The livestock subsector grew by 3%, and its share in agricultural GDP was 12% in 2013–2014. Livestock has propelled economic growth and food consumption in Bangladesh, though not without risk. At the household level, for example, evidence suggests that owning livestock may pose sanitation risks. Wardrop *et al.* (2018) found that households owning livestock and poultry in three countries (including Bangladesh) are at greater risk of contaminated drinking water, which could undercut effective biological utilization of nutrients.

Integrated agriculture programs at the household level, which include livestock and aquaculture, have great potential to improve food consumption, nutrition, and reduce poverty. Further research on designing and implementing nutrition-sensitive policies and programs that support households in safely incorporating fisheries and livestock into their livelihoods portfolio, with minimal risk to nutrition, should be explored.

Drivers of Diverse Diets in Bangladesh

The discussion above details various factors that drive dietary diversity, including gender and agricultural diversity. The importance of these factors and others is confirmed by recent evidence. Using the 2012 and 2015 BIHS data, Ahmed and Tauseef (2018) estimated the determinants of dietary diversity using two measures: the Food Consumption Score developed by the World Food Programme and household dietary diversity score. They found that diet diversity improves given the following:

- Household male head and spouse have higher levels of education.
- Agricultural diversity increases: household grew higher number of non-rice food crops last year.

- Women are more empowered (as measured by the Women's Empowerment in Agriculture Index).
- Households have a higher number of milking cows and are engaged in fisheries.
- Rice price increases (households respond to an increase in rice price by partially shifting consumption away from rice to other food items, which results in an increase in dietary diversity).

Relative food prices matter too. The inflation-adjusted, real price of rice fell by 53% in 35 years from 1982 to 2016. The falling price of rice has helped the rural landless and the urban poor, who purchase the rice they consume. The ultra poor cannot purchase enough rice to meet their energy requirements, despite a falling real price of rice. Therefore, the adoption of agricultural technology (that is, high-yielding and stress-tolerant seed varieties, fertilizers, and small-scale irrigation) by farmers and institutional innovations that made this price decline possible must be maintained.

However, the real price of several foods that are rich in nutrients demonstrates increasing price trends (Sen *et al.*, 2010). The increase in the real price of non-rice foods probably reflects supply-side constraints, largely related to low level of productivity per unit of land and underdeveloped agricultural value chains for these crops. If policies are not undertaken to increase the supply of non-cereal, nutrient-rich foods (such as pulses, fruits, vegetables and animal-sourced food), prices of these foods will continue to increase in the face of income and population growth. Consequently, the diet quality and nutritional status of the poor may deteriorate further. These observations have important implications for agricultural policy.

The Agriculture, Nutrition, and Gender Linkages (ANGeL) Project: an Example of a Government-led Initiative

IFPRI's research in Bangladesh shows that agricultural diversity improves household, maternal, and child dietary diversity, and that women's empowerment enhances both dietary diversity and agricultural diversity. Other recent collaborative research such as Alive & Thrive and the Transfer Modality Research Initiative, the latter undertaken jointly by IFPRI and the World Food Programme, have found that nutrition-oriented behavior change communication training improves household diet quality, child nutrition, and complementary feeding practices (Ahmed *et al.*, 2016; Menon *et al.*, 2016).

Motivated by this evidence, IFPRI designed a pilot project to bridge the gaps among agriculture, nutrition, and gender. 'Orienting Agriculture Towards Improved Nutrition and Women's Empowerment', also referred to as the Agriculture, Nutrition, and Gender Linkages (ANGeL) project, is a 3-year initiative (2015–2018) implemented by Bangladesh's Ministry of Agriculture. It aims to identify actions and investments in agriculture that will help increase farm household income, improve nutrition, and empower women. It was designed to generate definitive evidence on the critical pathways through which underlying drivers of nutrition can be addressed and scaled through nutrition-sensitive agriculture.

IFPRI uses a randomized controlled trial design to evaluate ANGeL's impact on five combinations of three types of interventions for promoting nutrition- and gender-sensitive agriculture through the following modalities:

- **Agricultural production:** facilitating the production of high-value commodities rich in essential nutrients through the diversification of crops, livestock, fisheries, and so on.
- **Nutrition knowledge:** conducting high-quality training focused on changing behaviors and improving knowledge of nutrition practices, such as cooking and preparation techniques.
- **Gender sensitization:** undertaking activities to empower women and raise their status while encouraging gender parity.

The ANGeL Project randomly selected 4000 farm households in 16 out of 64 districts in rural Bangladesh, with the majority receiving one of five interventions and a sixth group randomly chosen to not receive any project interventions (control group):

- Option 1: Nutrition trainings conducted by government agriculture extension agents.
- Option 2: Nutrition trainings conducted by trained community women hired by the project.

- Option 3: Agriculture Production trainings conducted by government agriculture extension agents.
- Option 4: Agriculture Production + Nutrition trainings conducted by government agriculture extension agents.
- Option 5: Agriculture Production + Nutrition + Gender Sensitization trainings conducted by government agriculture extension agents and project-hired facilitators for the gender component.
- Control (875 households).

ANGeL's design draws on a large, nationwide agricultural extension network. In Bangladesh, agricultural extension agents (mostly men) of the Department of Agricultural Extension (DAE) provide services mostly to male farmers to facilitate the adoption of agricultural technologies and modern agricultural production practices; women are rarely reached by DAE agents. ANGeL is deliberately designed to correct this gendered asymmetry in agriculture extension. ANGeL female beneficiaries receive agricultural production training alongside men, which enables them to participate in sole or joint decision-making on agricultural production and marketing (for example, what inputs to buy, crops to grow, what livestock to raise, what and how much produce to sell). On the other hand, men receive key messages on nutrition, since they are the primary buyers of food in rural Bangladesh (women having limited mobility due to religious and social norms of segregation).

ANGeL's initial quantitative impact results support strengthening the agriculture–nutrition–gender nexus (Ahmed *et al.*, 2018). Both men and women benefited from agriculture trainings, yet women learned more from the same trainings. Crop diversity increased substantially in homestead gardens, largely due to ANGeL's emphasis on homestead food production for nutritious crops. Farmers also adopted improved production practices on homestead gardens. In particular, women emerged as key contributors towards diversifying home gardens and exhibited nearly double the rates of adoption of vegetable production compared with men across all interventions with agriculture trainings. The initial analysis also consistently found that women were more likely to apply knowledge gained from agriculture production trainings to adopt various types of improved agriculture production practices, such as pest and disease control, seed production and care, and use of fertilizer. Similarly, improvements in nutrition knowledge were far greater for women and when trainings were combined. These improvements in knowledge had impacts on nutrition outcomes, with increases in household diet quality and child dietary diversity over the project period. The strongest improvements in empowerment, as measured by the abbreviated Women's Empowerment in Agriculture Index, were shown when agriculture, nutrition, and gender sensitization trainings were combined (Ahmed *et al.*, 2018). ANGeL's household approach empowered women and men in unique ways: while women became more empowered in asset ownership and income decisions (under option 5), men became more empowered in production and income decisions in select interventions (men's production and income decisions had statistically significant improvements under two interventions: option 2: nutrition BCC trainings delivered by government agriculture extension agents; and option 5: agriculture production, nutrition BCC, and gender sensitization trainings). Attitudes related to gender of both women and men also improved, with more women recognizing that they make important contributions to their communities.

ANGeL is the first ministry-led initiative that uses a rigorous impact evaluation to develop an evidence base to design and implement a national program. ANGeL's findings support the value of improving women's access to agricultural extension, and building the capacity of government agricultural extension agents to motivate behavior change for homestead food production and nutrition. Encouragingly, the government of Bangladesh plans to use the research-based evidence to scale up the most effective interventions all over the country.

Policy Conclusions

Agricultural growth is key to poverty reduction. Bangladesh's recent slowdown in agricultural growth, mainly due to decreased growth in rice production, needs to be addressed. Rice production must not be de-emphasized. Rather, rice cultivation should be intensified through investment research to increase productivity.

This will mean developing new technologies and innovations through research to address production problems in flood, drought, and salinity-induced stress conditions. Intensification of rice cultivation has the potential of releasing land for non-rice crop cultivation, without compromising rice production growth. Agricultural technologies must be disseminated to farmers through effective extension systems.

At the same time, the growth in production of non-rice crop and non-crop agricultural commodities must be augmented to improve the dietary diversity of the Bangladeshi population. The historical growth in rice production has not been matched by increased production (and consumption) of vegetables, fruits, milk, eggs and meat, adversely impacting diet quality. Reorienting agriculture for ensuring nutrition can be accomplished through various policy actions.

First, year-to-year price fluctuations are much larger for non-rice crops than for rice, indicating relatively high levels of market-induced risks for production of non-rice crops. Developing value chains to link producers to food processing industries and food supermarkets can help mitigate these risks. As discussed earlier, contract farming can also play an important role, as can an enabling policy environment for the private sector to develop nutrition-sensitive agricultural value chains. Investments in research can also potentially minimize production risks. Research can play an important role in increasing the productivity of non-staple crops, thereby reducing the cost of production. In addition to improving the productivity of non-staples, research can focus on developing vegetable varieties that: (i) grow well in off-seasons; (ii) are disease- and pest-resistant; and (iii) have high contents of important micronutrients.

Gender needs to be mainstreamed into all relevant agriculture–nutrition policies and programming, in light of the strong links between women's empowerment and agricultural diversity. Hiring more female agriculture extension agents under the Ministry of Agriculture's DAE, for example, could enhance agriculture extension's reach to smallholder farmers – both men and women. Beyond expanding agriculture extension's reach, nutrition messaging could also be integrated into the agricultural extension curriculum.

Finally, more evidence is needed. The government of Bangladesh has shown remarkable willingness to draw upon research to design its policies and large-scale programs. Country-driven nutrition-sensitive agricultural interventions like the government-led ANGeL project hold promise for generating context-specific policy lessons. These lessons can be applied to overcome Bangladesh's persistent challenges, and set it on the path toward sustained agricultural growth, poverty reduction, and nutrition security.

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A woman in Ethiopia prepares bread from the leaves of false banana, a nutritious root crop. The country has developed its first-ever Nutrition-sensitive Agriculture Strategy, addressing malnutrition through food production, agricultural income, and women's empowerment. (Ann Porteus)

16

Moving Towards Nutrition-sensitive Agriculture Strategies and Programming in Ethiopia

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Introduction

Ethiopia is a low-income country with a rapidly growing population of about 107 million people (UN, 2018). Most people still live in rural areas, and agriculture accounts for almost 77% of employment in the country. Urbanization is slowly on the rise, with approximately 20% of Ethiopians living in cities in 2016, compared with 15% in 2000 (World Bank, 2016). The country is also experiencing other demographic transitions, owing to a rapid decline in mortality and fertility. The share of people between 15 and 49 years of age, for example, estimated at 53% in 2000, may reach 65% by 2030 (UN, 2018).

Ethiopia faces serious nutrition challenges. It is estimated that 68% of adults were stunted as children, impacting their current productivity (AUC, 2014). More than 5 million children under 5 years of age remain chronically malnourished (CSA and ICF, 2016), impacting future generations. The country is currently implementing its second Growth and Transformation Plan (GTP 2016–2020), which sets an ambitious goal to become a lower middle-income country by 2025 (FDRE, 2015). Hence, investing in the children of today will be critical to support the objectives of the GTP.

This chapter begins with a discussion of Ethiopia's various nutrition-related indicators, which show the persistence of child and adult malnutrition, despite some progress. It discusses the major programs and policies that have been launched during the past two decades within the nutrition and agriculture sectors, and at the global level too, and the synergies (and remaining gaps) between them. The sum of these developments reflect Ethiopia's slow but promising shift to a coordinated, multisectoral approach to improving nutrition.

Remarkable Improvements Alongside Stagnation

Ethiopia has seen much improvement within health and nutrition during the past decade. Several health outcomes among women and children have vastly improved, including under-5 mortality which declined from 123 to 67 deaths per 1000 live births between 2005 and 2016 (CSA and ICF, 2016). The country also experienced an impressive reduction in stunting rates, which dropped from 51% to 38% between 2005 and 2016. Exclusive breastfeeding among children under the age of 6 months has consistently improved over time, from 49% in 2005 to 58% in 2016 (CSA and ICF, 2016).

Despite this progress, child wasting persists, declining slowly from 12% in 2005 to 10% in 2016 (Fig. 16.1) (CSA and ICF, 2016). Children older than 6 months continue to receive a monotonous, low-nutrient diet. The proportion of children between 6 and 23 months who get a minimum acceptable diet (which relates to an adequate diversity in food groups and meal frequency) only rose from 4% to 7% between 2011 and 2016. Low child dietary diversity is a challenge, due to a combination of poor access to nutritious foods and limited knowledge about appropriate feeding practices (Hirvonen and Hoddinott, 2014; Stifel and Minten, 2015; Hirvonen *et al.*, 2016). Adult women also consume on average only 1.67 out of 10 food groups (EPHI, 2013). Nearly one-quarter of women are underweight (CSA and ICF, 2016).

Wide geographic disparities also exist. While most regions saw a reduction in stunting in 2011–2016, four regions (Afar, Amhara, Benishangul-Gumuz, and Dire Dawa) still have stunting rates higher than 40%. Stunting levels of rural children have been consistently higher than those in cities, while rural children also consume fewer food groups. Whether a rural district has a food surplus or shortage does not seem to make much difference in terms of nutrition outcomes (Berhane *et al.*, 2013, 2017a, b; UNICEF, 2018; EPHI, 2017; EDRI, 2017).

The Health Extension Program, a Keystone Nutrition-specific Intervention

For many decades, nutrition in Ethiopia was addressed through ad hoc interventions, primarily designed to respond to emergencies and mainly implemented by the health sector. In 2003, the Ministry of Health reformed the delivery of basic health services with the launch of the

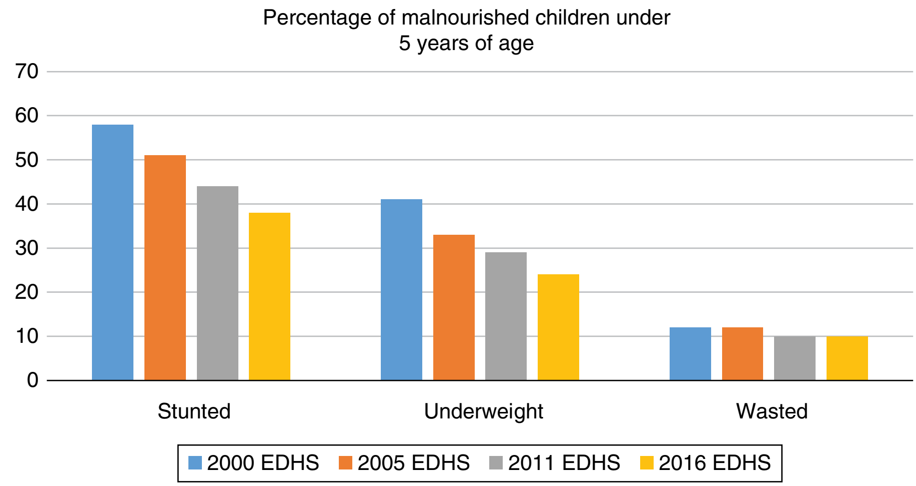

Fig. 16.1. Key nutrition outcomes, Ethiopia 2000–2016 (adapted from CSA and ICF, 2016).

Health Extension Program (HEP), leading to a quick roll-out of a set of basic preventive health services in rural communities. One year later, various large-scale nutrition programs were introduced nationally, allowing for more widespread access to vitamin A supplementation, deworming, and community outpatient therapeutic programs. In 2008, most of these nutrition programs were integrated as part of the HEP. Also in 2008, the HEP added a new Community Based Nutrition (CBN) program to its growing portfolio, focusing predominantly on maternal and adolescent nutrition counseling, monthly growth monitoring and promotion sessions for children, education on infant and young child feeding practices, treatment referrals, and the promotion of sanitation and hygiene. By this time, the services provided under the HEP included 16 interventions, spread across four thematic areas: (i) disease prevention and control; (ii) family health; (iii) hygiene and environmental sanitation; and (iv) health education and communication. Nutrition services were provided as part of the family health focus area. All of these HEP services were delivered by approximately 32,000 health extension workers, posted in pairs at the community level. The health extension workers receive a 1-year pre-service training, complemented by various on-the-job refresher trainings on specific topics (Lemma and Matji, 2013; Workie and Ramana, 2013; Wirth *et al.*, 2016).

HEP has made a wide variety of preventive health services in rural areas available, including those aimed at improving nutrition. The gradual expansion of its delivery model allowed for an increased uptake of nutrition services by rural women and children between 2005 and 2011 (Wirth *et al.*, 2016) and an increased access to maternity care (Buisman *et al.*, 2017), which may have contributed to improved child nutritional outcomes. The CBN included a focus on nutrition counseling, such as infant and child feeding practices. A survey showed that exposure to CBN's large-scale social and behavior change communication interventions was associated with improvements in infant and young child feeding practices, though it did not lead to significant differences in stunting, underweight, and wasting (Kim *et al.*, 2016). Recent evidence suggests that an increase in the median duration of exclusive breastfeeding, from 2.5 to 3.6 months between 2000 and 2016, may have led to reduced infection rates among young children (Hirvonen *et al.*, 2018).

Additionally, improved sanitation and piped water interventions carried out by the HEP in 2001–2011 were associated with better child growth outcomes, maternal nutrition, and birth size (Headey, 2014, 2015). Other factors, such as agricultural growth associated with income growth and improved food security, have also been identified as important drivers of nutritional change between 2000 and 2011 (Headey, 2014).

Towards a systematic approach to nutrition

Nutrition was long considered by Ethiopian policy-makers as the mandate of the health sector. The results of the 2005 Demographic and Health Survey, however, triggered an important shift in perception that chronic undernutrition can coexist with agricultural surpluses and that increased food production is not a sufficient solution to hunger (Mokoro, 2015). This realization led to the development of the first National Nutrition Strategy (FDRE, 2008) and the National Nutrition Program (NNP 2008–2013), both of which embraced a shift from emergency response to a systematic preventive and promotive approach to malnutrition, and introduced the concept of multisectoral collaboration. Most of the interventions proposed under the NNP were still driven by the health sector but the program established modest linkages with other sectors, including water and sanitation, education, and agriculture. Although NNP's multisectoral components were implemented only at a small scale, and were not yet fully reflected in agriculture sector plans, the National Nutrition Strategy and NNP marked a first important step towards a more coordinated approach to addressing malnutrition (Mokoro, 2015).

The momentum to address malnutrition through agriculture policies, and scale up efforts, also owes much to Ethiopia's involvement in global initiatives. In September 2010, Ethiopia joined the Scaling Up Nutrition (SUN) movement, inspiring it to strengthen its multisectoral coordination mechanisms, and mobilizing its agriculture sector (Mokoro, 2015). Ethiopia's involvement in the Comprehensive Africa Agriculture Development Program (CAADP, 2013) also set off discussions about how nutrition could be better incorporated into the 2010–2020 Ethiopia Agricultural Sector Policy and Investment Framework (Hodge *et al.*, 2015; Beyero *et al.*, 2016). In addition, an assessment launched by the African Union Commission in 2013 on the social and economic impact of undernutrition in Africa has been influential for national policy formulation. It included an Ethiopia country case study, which demonstrated that the total losses in productivity due to stunting for 2009 were equivalent to 16% of Ethiopia's gross domestic product (GDP): manual intensive work, such as agriculture activities, represents 24% of this loss. The availability of these data played a crucial role in encouraging the involvement of the agriculture sector in nutrition (AUC, 2014; Mokoro, 2015). Ethiopia also endorsed the UN General Assembly's 2015 Millennium Development Goals (MDGs) and the 2030 Sustainable Development Goals (SDGs), incorporating them into its national development frameworks.

As previously mentioned, the National Nutrition Strategy and NNP (2008–2013) represented a first step toward multisectorality, and Ethiopia's participation in various global initiatives created a nationwide and high-level consensus about the need for a multisector response to nutrition. Within this context, the revised NNP (2013–2015) was developed with the participation of many sectors, including agriculture. Contrary to the NNP 2008–2013, the revised program appeared as a federal government publication, signed not only by the state minister of Health, but also by eight other state ministers.

The NNP 2013–2015 used a life cycle approach, focusing on the 1000-day window (from conception to 2 years of age, the most critical time to make an impact on child nutrition), and extensively described the multisectoral nature of nutrition. To enhance implementation, sector interventions were well defined and linked with an accountability framework. The agriculture sector agreed to support the NNP by increasing the production and consumption of nutritious food, expanding research related to nutritious food, and mainstreaming gender and nutrition within its flagship programs. The Ministry of Agriculture was also assigned an important role in coordinating the NNP. The National Nutrition Coordination Body was notably co-chaired by the state Minister of Agriculture, who was also responsible for the Productive Safety Net Program (PSNP), discussed later in this chapter. The state minister's involvement in NNP 2013–2015 and in national nutrition coordination prompted him to promote the nutrition agenda during the redesign of the PSNP in 2014.

The Sequota Declaration (2015) marked another high-level political commitment to a multisectoral approach for nutrition. In line with the SDGs, this pledge aims to eliminate undernutrition by 2030. Its implementation models involve the delivery of integrated community services by all sectors. As a result, Sequota will not create new interventions but instead promotes local coordination platforms that take stock of available interventions and encourages their complementarity, in order to ensure that households receive a comprehensive set of nutrition-sensitive and nutrition-specific services. The agriculture sector will support the Declaration through nutrition-sensitive initiatives under its existing programs, such as the Agriculture Growth Program (AGP) and the PSNP. The innovation phase of the Declaration's action plan is now operational in 34 food-insecure districts and marks a transition towards a highly integrated, decentralized approach. In contrast to other programs, the coordination of the Sequota Declaration Action plan is not being undertaken by line ministries but rather by units placed at the level of regional and district administration heads. By way of implementing Sequota, these structures establish 'community labs' at the district level, complemented by satellite demonstration sites at the community level. Lessons learned from this innovation phase will be used for further expansion toward other districts.

Shortly following the Sequota Declaration, the second NNP (NNP II 2016–2020) was being formulated (FDRE, 2016a). This NNP incorporates a nutrition-sensitive approach, following the conclusions of *The Lancet* 2013 series, and defines a set of nutrition-specific and sensitive interventions that can help Ethiopia meet the SDGs. The nutrition-sensitive interventions for the agriculture sector comprise agriculture, natural resources, livestock, forest, fisheries, and social protection. Key interventions relate to increasing the productivity and consumption of nutritious food, promoting adequate technologies for food processing, and strengthening the sector's nutrition-sensitive planning, capacities and research. The NNP II continues to apply a life cycle approach, but also includes a focus on adolescent girls and addresses overweight and emerging diet-related non-communicable diseases. It identifies a wide set of interventions across sectors, and emphasizes the importance of strengthening multisectoral nutrition coordination and capacity building. To facilitate implementation, the program includes strategic objectives and interventions across relevant sectors, operational guidelines for multisector coordination, and a costed action plan.

The high-level commitment to nutrition was also reflected in the second Growth and Transformation Plan (GTP 2016–2020), which presents the national policy framework for becoming a lower-middle-income country by 2025 (FDRE, 2015). For the first time, addressing stunting was presented as a major factor that can help meet the country's development goal. The GTP 2016–2020 holds multiple sectors responsible for reducing stunting from 40% in 2016 to 26% in 2020, creating a space for high-level discussions on how to achieve this target. Table 16.1 provides a non-exhaustive list of relevant programs and initiatives mentioned in this chapter.

Nutrition Goals Within the Agriculture Sector

Ethiopia's national agriculture strategy has long prioritized increasing food security, with an emphasis on improving the productivity of major staples. This has led to many successes, but the focus on food security has given little incentive to implement nutrition-sensitive agriculture interventions (Taylor, 2012; Hodge *et al.*, 2015). Early agriculture policy and program documents, such as the Agriculture Sector Policy and Investment Framework 2010–2020 and early phases of PSNP and AGP, included nutrition-related indicators, but little operational guidance was provided on how to reach these targets and actual implementation was seldom monitored (Bossuyt, 2014; Chipeta *et al.*, 2015; Mayer and Baheru, 2015; FAO, 2017).

By 2015, nutrition-related capacity within the agriculture sector remained limited. Despite high-level political commitment, agriculture-sector technicians and implementers experienced many challenges in understanding how their sector can contribute to the NNP. Nutrition was still seen by many as a health and emergency issue (Hodge *et al.*, 2015; Beyero *et al.*, 2016).

As the NNP 2016–2020 was being designed, agriculture stakeholders were also beginning discussions on a National Nutrition Sensitive Agriculture Strategy, a process that took almost 2 years, but which allowed for different agricultural ministries to gain a better understanding of their responsibilities and tasks

Table 16.1. Select nutrition and agriculture interventions and policies in Ethiopia.

Program/Strategy	Years	Activities/Comments
Health Extension Program (HEP)	2003 – ongoing	Comprises 16 interventions under four themes, one of which (family health) covers nutrition Gradual expansion of nutrition services (vitamin A supplementation, de-worming, and community outpatient therapeutic programs) 2008: HEP includes Community Based Nutrition (CBN) Program, which focuses on maternal and adolescent nutrition counseling and education, child growth monitoring, and sanitation and hygiene. By 2013, CBN is operational in all PSNP woredas 2017 onwards: CBN is being transitioned into the Comprehensive and Integrated Nutrition Services (CINUS), which promotes adolescent, maternal, infant and child feeding practices; and links social behavior change communication with PSNP and agriculture extension services
National Nutrition Strategy	2008	Introduced the concept of multisectoral collaboration
National Nutrition Program	2008–2013	Implementation of the program was mainly led by the Health sector but multisectoral collaboration was introduced at modest levels
Revised National Nutrition Program	2013–2015	Used life cycle approach and focused on 1000-day window Signed by nine ministries Sector interventions linked with accountability framework Develops coordination mechanism and assigns the Ministry of Agriculture with an important role in coordination
Second National Nutrition Program (NNP II)	2016–2020	Continues to apply a life cycle approach, but also includes focus on adolescent girls, and addresses overweight Defines nutrition-specific and nutrition-sensitive interventions that can help Ethiopia meet the SDGs Emphasizes multisectoral coordination and capacity building Signed by 13 ministries Expands further on the role which the agriculture sector can play
Sequota Declaration	2015	Marked high-level political commitment to address malnutrition, aiming to eliminate undernutrition by 2030 Promotes implementation model which focuses on coordinating existing interventions, and brings multisectoral set of interventions at community level Implementation of the innovation phase is ongoing
2nd Growth and Transformation Plan	2016–2020	National policy framework for making Ethiopia a lower-middle-income country by 2025 Stunting reduction seen as crucial to country's development
National Nutrition-sensitive Agriculture Strategy	2016	Calls on agriculture sector to address malnutrition through food production and productivity; agricultural income; and women's empowerment 2018: Nutrition Case Team established under the state minister Nutrition mainstreamed in agricultural subsectoral strategies (e.g. extension, horticulture, post-harvest)

Productive Safety Net Program (PSNP)	Started in 2005 Phase 3 (2009–2013) Phase 4 (2015–2020)	PSNP-3 includes some nutrition-sensitive interventions, but these are not systematically implemented PSNP-4 expands on nutrition-sensitive aspects, which are now part of the program. Linkages with HEP are enhanced. Promotes access to health and nutrition services for women and children, women's empowerment and improved water, sanitation, and hygiene Nutrition outcomes-level indicators for children and mothers included in results framework and monitored (anthropometric indicators, diets of children and women) Multisectoral coordination guided by PSNP Nutrition Task Force, chaired by Agriculture and co-chaired by Health Ministry
Agriculture Growth Program (AGP)	Phase 1: 2011–2015 Phase 2: 2015–2020	AGP-2 (2015–2020) integrates focus on increased production of nutritious foods, increased households' dietary diversity, and gender
Sustainable Undernutrition Reduction (SURE) program	Launched in 2017	First government-led multisectoral integrated health and agriculture sector program Enhances CBN by using existing health and agriculture extension platforms to improve complementary feeding and dietary diversity

as they relate to nutrition. The National Nutrition Sensitive Agriculture Strategy was launched in November 2016 (FDRE, 2016b), linking CAADP, the initiatives of the three agricultural ministries, the NNP, and the Sequota Declaration. The strategy calls for the sector to address malnutrition through three pathways: food production and productivity, agricultural income, and women's empowerment, all aligned with six strategic objectives. The strategic plan includes an accountability matrix, but indicators relate mainly to activities and processes, not outcomes. The modalities to measure progress are still being defined (FDRE, 2016b). The strategy harnesses the full potential of the agriculture sector, including its subsectors and ministries, to support the NNP. Nutrition has been mainstreamed in some of the agricultural subsectoral strategies, such as the extension strategy, horticulture strategy, and the post-harvest strategy (MoANR, 2018). The strategy also includes provisions to strengthen multisectorial coordination within the agriculture sector. To support the implementation of the strategy, the agriculture ministries identified either nutrition focal points or a nutrition case team. By mid-2018, an overarching sectoral Food and Nutrition Coordination office was established at the ministry.

The government of Ethiopia is also currently in the process of adopting a National Food and Nutrition Policy which will provide an overall policy framework on food and nutrition, and will revise the respective coordination structures. This new policy was approved in November 2018.

A Tale of Nutrition Sensitivity in Two Flagship Agricultural Programs

Since 2005, the Ministry of Agriculture has taken a particularly strong leadership position in the national response to food security and emergencies. It has managed a safety net, directed humanitarian food assistance, and coordinated the response to acute malnutrition in emergency situations. The ministry also introduced high-level objectives of improved nutrition outcomes into two of its major programs, the third phase of the PSNP (PSNP-3, 2009–2014) and the first Agriculture Growth Program (2011–2015). At first, these objectives were not translated into specific programmatic interventions, as it was largely assumed that increased agricultural production and commercialization, or increased household income through the safety net, would lead to improved nutrition. Initially, progress in reaching these objectives was rarely measured (Bossuyt, 2014; Mayer and Baheru, 2015).

Productive Safety Net Program (PSNP)

The government launched PSNP in 2005 in order to address food insecurity through a comprehensive approach. Coordinated by the Ministry of Agriculture, PSNP provides predictable community-level transfers to poor and food-insecure households in chronically food-insecure districts. The program's coverage and interventions have expanded gradually over time. A few nutrition-sensitive provisions were introduced in the PSNP-3 design, but their implementation was hampered by lack of training, little high-level buy-in, and minimal monitoring (Bossuyt, 2014). Consequently, evidence showed that PSNP had little impact on nutrition outcomes (Berhane *et al.*, 2017a).

Informed by these earlier experiences, PSNP-4 (2015–2020) took a new strategic direction, aiming to contribute systematically to the NNP by addressing various determinants of malnutrition, including maternal and child health, vaccination, infant and young child feeding practices, dietary diversity, women's empowerment and water, sanitation, and hygiene. Health seeking behavior of pregnant and lactating women is promoted through soft conditionalities which relate to antenatal care, vaccination, child health check-ups, and participation in the CBN. The community-level implementation of these provisions requires very close collaboration between agriculture- and health-extension workers. Nutrition-related outcomes, such as reduced child wasting and stunting, and improvements in children's diets, are now included as part of the monitoring and evaluation framework (FDRE, 2014).

Under PSNP-4, the program's coverage has expanded, now reaching 8 million chronically food insecure people across 329 districts. The roll-out of a wide set of new provisions has required a significant number of start-up and capacity building activities. The launch of PSNP-4 also coincided with the El Niño drought, diverting attention towards the emergency response, and delaying the program's implementation.

Many of the nutrition-sensitive provisions were new to PSNP implementers. During the first 2 years of PSNP-4, the program management therefore focused on creating tools and building capacity for multisectoral implementation. During this process, program stakeholders were guided by a PSNP Nutrition Task Force, chaired by the Ministry of Agriculture and co-chaired by the Ministry of Health. Delivering these tools from the regional to the community level has been challenging, mainly because of the program's large coverage, drought-related obstacles, and budget restrictions. By December 2017, most federal, regional, and zonal stakeholders knew about these new nutrition-sensitive provisions; in contrast, only in a limited number of districts had the agriculture and health extension workers been trained on the implementation modalities, delaying delivery of nutrition-sensitive interventions to the community (Bossuyt, 2017; World Bank, 2018a, b).

Currently, PSNP implementers are further focusing on training agriculture- and health-extension workers to deliver nutrition-sensitive provisions to PSNP clients (World Bank, 2018a, b). While the initial progress in implementation was lower than expected, the building blocks have been established and it is expected that most activities will roll out during the next year.

Agriculture Growth Program (AGP)

The AGP was launched in 2011 to increase agricultural productivity and market access for key crop and livestock products in districts that have a high growth potential, primarily based on agroecological conditions and access to markets. These districts' nutrition outcomes are similar to those of food-insecure districts (Berhane *et al.*, 2013, 2017a, b; EDRI, 2017). The first phase of AGP (2011–2015) had no particular implementation focus on nutrition, though it did comprise a few nutrition-sensitive interventions (Mayer and Baheru, 2015). Some partners implemented complementary nutrition programs in AGP districts, such as the USAID-funded ENGINE program (2011–2016) (Empowering the New Generation to Improve Nutrition and Economic opportunities) which used multisectoral interventions to improve the nutritional status of women and young children, but these project outcomes were not necessarily reflected in AGP programmatic planning and reviews.

Inspired by the NNP-2, the GTP, and the PSNP-4 design process, the government of Ethiopia designed the second phase of AGP (2015–2020) to be more nutrition and gender sensitive. AGP-2 focuses not only on increasing agricultural productivity and commercialization of smallholder farmers, but also on increased production of nutritious foods, increased households' dietary diversity, and gender. The results framework also allows program implementers to measure progress in the implementation of these nutrition-sensitive provisions. The implementation of nutrition-sensitive agriculture is a new concept for AGP stakeholders. Similar to PSNP, the AGP leadership spent the first year of implementation creating capacities and tools to help operationalize the program's nutrition-sensitive provisions, and it is expected that actual implementation of the nutrition- and gender-sensitive provisions will expand in the near future.

Ethiopia's newfound commitment to nutrition is reflected in its funding: nutrition budgeting more than doubled between mid-2013 and mid-2016. The increase in funding was largely driven by investments in nutrition-sensitive programs; in 2015–2016, nearly US$455 million was allocated to nutrition, 73% of which was for nutrition-sensitive interventions, including the One WaSH National Program (OWNP) and nutrition-sensitive provisions of the PSNP (FDRE, 2017). The roll-out of the nutrition-sensitive interventions under AGP-2 is expected to increase these expenditures even more.

Linking Health and Agriculture Front Line Workers: Toward More Integrated Government-led Implementation Models

The 2016 Demographic and Health Surveys (DHS) demonstrated an encouraging downward trend in stunting rates, but also showed that more needed to be done in order to reach the NNP objective of reducing stunting from 40% to 26% by the year 2020. In response, several interventions were initiated in 2017 to apply a more integrated approach at the community level, linking CBN with nutrition-specific and nutrition-sensitive interventions provided by agriculture- and health-extension agents. While in the past, various projects had successfully applied a multisectoral approach, most of them were limited to specific geographic areas. Lessons from these programs are now being considered by the ministries, informing some interesting government-led programs that seek to bring the frontline workers of these two sectors together.

For example, in 2017, the Ministry of Health redesigned and expanded the CBN into the Comprehensive and Integrated Nutrition Services (CINUS), which uses a life cycle approach to promote optimal adolescent, maternal, infant and child feeding practices, and link social behavior change communication with PSNP and agriculture extension services. Health extension and agriculture development agents are trained together and are expected to provide complementary services. In early 2018, CINUS was being rolled out in 100 PSNP districts (Bossuyt, 2017; UNICEF, 2018).

The Sustainable Undernutrition Reduction (SURE) program was also launched in 2017, and is the first government-led multisectoral integrated health and agriculture sector program. SURE enhances the CBN by using existing health and agriculture extension platforms to provide additional services that aim to improve complementary feeding and dietary diversity. The program, currently implemented in 50 districts, promotes joint home visits by health extension and agriculture development agents, and provides inputs and capacity development for homestead gardening and consumption of a diverse diet (EPHI, 2017).

Both CINUS and SURE use community-based farmer training centers and health posts as entry points, but also work with schools, saving associations, livelihood groups, and various other community groups, applying a wide set of communication approaches to promote nutrition messaging. Where geographic coverage overlaps, they also take advantage of PSNP gatherings to deliver nutrition behavior change communication to PSNP clients.

Evidence Matters

Another factor that has helped raise the profile of nutrition in multisectoral policies and programs and engaged the Ministry of Agriculture is the availability and use of evidence. Ethiopia has been very receptive to using global evidence to inform dialogue on and design of multisectoral nutrition interventions and policies. The 2013 *The Lancet* series and various studies undertaken by the International Food Policy Research Institute (IFPRI) were used as reference materials by policy-makers seeking to understand agriculture–nutrition linkages during the design and implementation of the NNP 2013–2015 (Mokoro, 2015; Beyero *et al.*, 2016; Pelletier *et al.*, 2018). Evidence from the 2005 DHS helped policy-makers realize that increased food production is not a sufficient solution to hunger (Mokoro, 2015). The application of the PROFILES model in 2012 was a key element in convincing initially skeptical sectors about the need to apply a multisectoral approach through a wide range of interventions (FDRE, 2012). The *Cost of Hunger* study commissioned by the African Union Commission, which concluded that a 10% reduction in stunting and 5% reduction in underweight by 2025 could yield annual average savings of US$784 million, resonated with the Ministry of Finance and influenced policy formulation (AUC, 2014).

During the design phase of PSNP-4, IFPRI shared the results of three rounds of anthropometric surveys carried out in PSNP districts, which showed that PSNP had had no impact on nutrition outcomes (Berhane *et al.*, 2017a, b). These results swayed stakeholders to support the nutrition-sensitive design of PSNP-4 (Bossuyt, 2017). Furthermore, the *Cost of a Healthy Diet in Rural Ethiopia* series carried out by Save the Children, which concluded that most rural households cannot afford a nutritious diet (STC, 2014), was used as supporting evidence to add pulses to the PSNP-4 transfer to households.

Evaluations of PSNP and AGP, which include information on nutrition outcomes in various settings, are considered credible sources for policy-making processes because of their large geographic coverage (Beyero *et al.*, 2016). The implementation of CINUS, SURE, and the Sequota Declaration are also being accompanied by rigorous monitoring and evaluation, which will inform future expansion.

Despite the elevated role of evidence, there does not exist a national harmonized nutrition-sensitive agriculture research agenda. The Ethiopian

Institute of Agricultural Research focuses mainly on food production, food characterization, and food processing technologies, although it has undertaken work on biofortification. CGIAR's Agriculture for Nutrition and Health program recently identified research streams that can support the implementation of sustainable food systems approaches for improved nutrition, as guided by the NNP and the Nutrition Sensitive Agriculture Strategy (Gebru *et al.*, 2018). The program is currently also undertaking research that will guide the development of food-based dietary guidelines, another research priority of the NNP.

The Way Forward: Addressing the Challenges

Global and national nutrition policies have influenced the design of large nutrition-sensitive agriculture programs in Ethiopia. The mainstreaming of nutrition in these flagship programs has created a better understanding of the potential but also the challenges facing the agriculture sector's nutrition-sensitive approach. These discussions have in turn influenced the development of the first-ever national Nutrition Sensitive Agriculture Strategy. While there is now general policy and strategic consensus on how the sector can support the national nutrition agenda at the federal level, the next step will be to implement this approach at the decentralized and community levels, where there is still limited understanding on how agriculture can contribute to nutrition. Setting up a high-level sector coordination system and building relevant sectoral capacities for nutrition will be necessary in order to move from a fragmented to a comprehensive implementation approach for nutrition-sensitive agriculture. Predictable funding for nutrition in the sector's budget is also key, as are sectoral accountability and monitoring of nutrition indicators.

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A lemon vendor at a wholesale fruit market in Kolkata, India. India is the world's largest producer of lemons, much of which are exported to Gulf countries. (Abhijit Kar Gupta)

17

Unraveling India's Malnutrition Dilemma – a Path Toward Nutrition-sensitive Agriculture

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Introduction

Following the Green Revolution, India successfully increased agricultural productivity and overall food production, achieving a surplus in cereals for the first time ever and cementing a national focus on calorie availability. In subsequent decades, as the economy continued to grow, the country experienced a significant decline in poverty levels. Despite this momentous achievement, the rate of malnutrition in India remains stubbornly high. Between 1990 and 2009, India had the highest proportion of underweight children when compared with Bangladesh, Bhutan, Pakistan, Nepal, and Sri Lanka, despite its relatively higher per capita Gross National Income (GNI) growth (Dreze and Sen, 2011). Across the 29 Indian states, there is also much variation in malnutrition rates: in 2015, the prevalence of stunting ranged from 19.7% in Kerala to 50.4% in Uttar Pradesh (IIPS and ICF, 2015). Simultaneously with slow progress in combating child stunting and micronutrient malnutrition, overweight and obesity are also on the rise. The prevalence of obesity grew from 12.6% in 2005–2006 to 20.7% in 2015–2016 among women and from 9.3% to 18.9% among men (IIPS and ICF, 2015).

In this chapter, we make the case for India to shift to a nutrition-focused agricultural sector that goes beyond staple grain productivity to emphasize the production and consumption of micronutrient-rich foods. The chapter first reviews the nutrition trends in India, characterized by slow progress in addressing high and variable rates of malnutrition. It then assesses the policies that have influenced agricultural growth trajectories and safety-net programs to highlight the major challenges and disconnects in agriculture and nutrition policy. Finally, it calls for integrating some elements that a food-systems approach would consider, such as income, availability of nutritious food, intra-household distribution, and the health environment, as a way forward in addressing India's malnutrition dilemma.

Malnutrition in India: Major Challenges

Data from India's National Family Health Survey (NFHS) from 2015 painted a mixed picture of nutrition in India. On the one hand, malnutrition, anemia, and low BMI among children and adults showed much improvement from 2005–2006 to 2015–2016 (Table 17.1). The prevalence of stunting and underweight during this period declined by 20% and 16%, respectively, as did anemia in children (16% decline), women (4% decline) and men (6% decline). The prevalence of underweight decreased from 35.5% to 23% in women and from 34% to 20% in men.

However, most other statistics show discouraging trends. The prevalence of wasting among children is on the rise and is among the highest in the world. Anemia among children and adults in India is still extremely high. The anemic status of a mother influences the propensity of her child to be stunted or wasted, and anemia in children may lead to impaired cognitive development, increased morbidity from

Table 17.1. Change in prevalence of malnutrition, micronutrient deficiency and overweight or obesity figures in India (2005–2006 to 2015–2016).

Prevalence	NFHS-3 (2005–06)	NFHS-4 (2015–16)	Change
Stunting (children < 5 years)	48.0	38.4	–20.00%
Wasting (children < 5 years)	19.8	21.0	6.06%
Underweight (children < 5 years)	42.5	35.7	–16.00%
Anemia (children 6–59 months)	69.4	58.5	–15.71%
Anemia (women)	55.3	53.0	–4.16%
Anemia (men)	24.2	22.7	–6.20%
Men with BMI < 18.5 kg/m^2	34.2	20.2	–40.94%
Women with BMI < 18.5 kg/m^2	35.5	22.9	–35.49%
Overweight or obese men (BMI ≥ 25.0 kg/m^2)	9.3	18.9	103.23%
Overweight or obese women (BMI ≥ 25.0 kg/m^2)	12.6	20.7	64.29%

infectious disease, and stunting and wasting (Bentley and Griffiths, 2003; Murray-Kolb and Beard, 2009; Diamond-Smith *et al.*, 2016). Obesity and overweight prevalence among adults are also rising, highlighting the dual challenge of underweight and obesity. NFHS 2015–2016 shows that the proportion of thin women is higher in rural areas compared with urban areas and the opposite for overweight and obesity, a reflection of an increase in overweight or obesity as household income increases.

Malnutrition rates in India remain high in comparison with other countries and regions with similar and even lower income levels. Many countries in Africa south of the Sahara and in South Asia show better performance in child malnutrition indicators (Table 17.2).

Figure 17.1 shows significant regional variations in the prevalence of malnutrition among Indian states, an indication of socioeconomic inequalities but also differences in governance, agricultural growth, and the public provisioning of basic services. Poorer regions have higher rates of undernutrition, but even within states the variations are determined by whether the region is rural or urban and by agroecological differences. States with higher per capita income, such as Andhra, Goa, Kerala, and Tamil Nadu, have lower child and malnutrition rates but a higher prevalence of overweight and obesity. Alarmingly, the prevalence of adult overweight or obesity in some of these states has almost doubled.

The Policy Environment and India's Nutritional Challenges

Agriculture is closely linked with nutrition and food security in three ways: (i) agricultural production determines the availability of food; (ii) production reduces the real cost of food; and (iii) agricultural livelihoods provide incomes to farming households that can be used to access nutritious and diverse foods (Ivanic and Martin, 2008; Swinnen and Squicciarini, 2012; Pingali *et al.*, 2015). Countries that proactively support pro-agricultural growth policies tend to see better child development indicators compared with countries that do not (Webb and Block, 2012). However, agricultural policy alone is insufficient and needs to be supported by strong nutrition policy. In this regard, the disconnect between agriculture and nutrition policy in India is especially glaring.

Agriculture policy – from getting the price right to distribution

The Green Revolution in the late 1960s ushered in a new approach toward agricultural development in India. The introduction of improved seeds along with investments in infrastructure such as irrigation and subsidized access to fertilizers and pesticides led to massive gains in agricultural productivity (Pingali, 2012). As food policy in India centered on promoting cereal-based production systems to meet the population's calorie requirements (Varshney, 1998), government policies in turn prioritized the sustained production of wheat and rice and their distribution to poor consumers. Measures were also taken to invest in research and development and extension services (Tilburg *et al.*, 2000), and the Public Distribution System (PDS) directly procured and distributed cereals on a national scale (de Janvry and Subbarao, 1986; Freebairn, 1995; Goldman and Smith, 1995; Dorward

Table 17.2. Child Malnutrition in Africa south of the Sahara and in South Asia.

Region/Countries	Stunting	Wasting	Underweight	Source
Africa south of Sahara	33.2	7.8	16	Akombi *et al.*, 2017 (based on DHS 2016 data)
Nepal	36	10	27	MoH Nepal *et al.*, 2017
Bangladesh	36	14	33	NIPORT *et al.*, 2014
Sri Lanka	17	15	20.5	DCS and MoHNIM, 2017
Pakistan	45	11	30	NIPS and ICF, 2013
India	38.4	21	35.7	IIPS and ICF, 2015

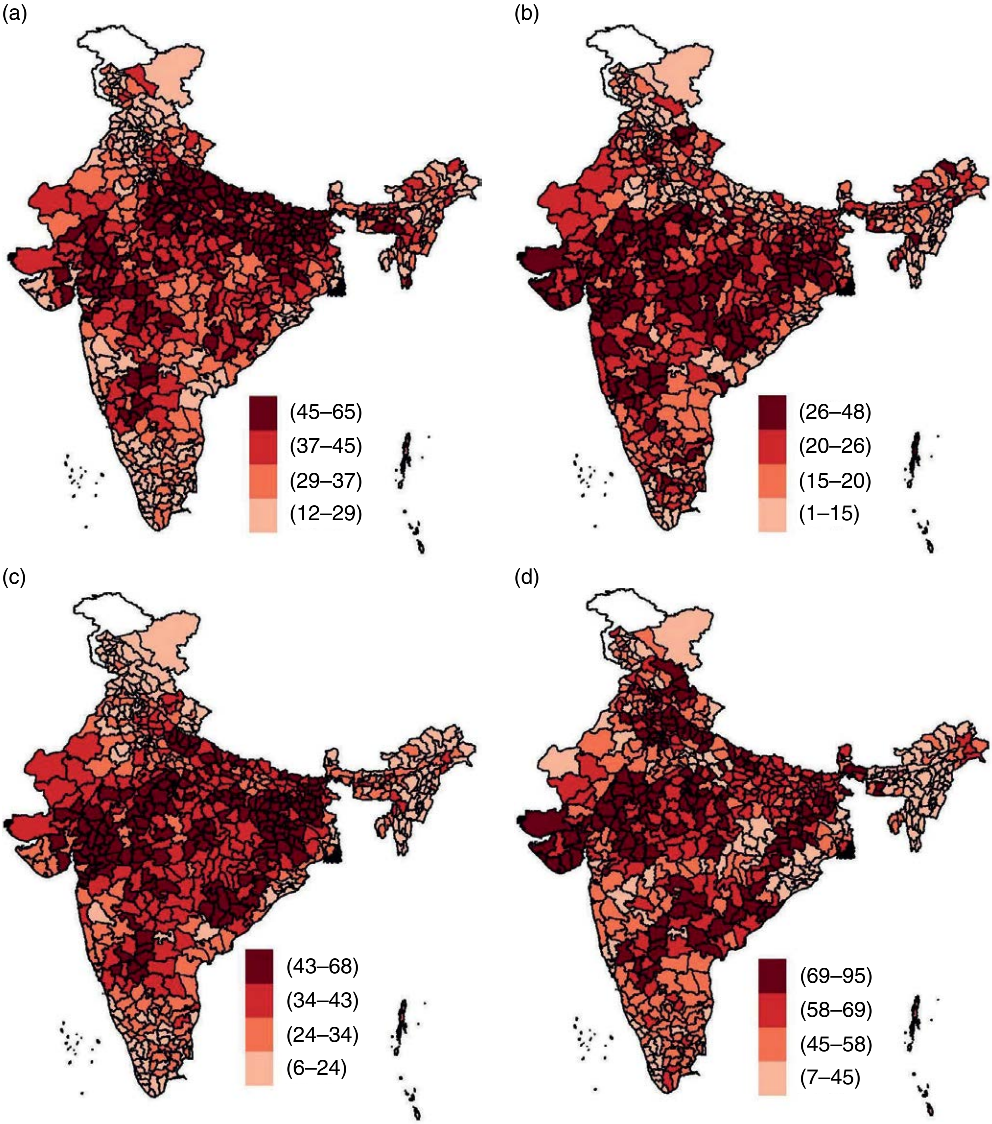

Fig. 17.1. District-level variation in child malnutrition (2015–2016), generated using NFHS 2015–16 district factsheets. (a) Children under who are stunted (%). (b) Children under 5 who are wasted (%). (c) Children under 5 who are underweight (%). (d) Children aged 6–59 months who are anemic (%).

et al., 2004). The government also set the Minimum Support Price (MSP) at the start of each growing season to ensure that when market prices fall below the MSP, government agencies would step in and procure from farmers. (Although initially only for wheat and rice, MSP currently extends to pulses, coarse grains such as sorghum, pearl millet, barley, oilseeds such as groundnut, rapeseed, mustard, soybean, sesame, sunflower, safflower, nigerseed, and to other products such as copra, cotton, and raw jute. However, procurement is still exclusive to wheat and rice and in the past 2 years in limited quantities to pulses in some states.)

These measures helped increase the per capita availability of food grains from 140 kg in 1950 to 160 kg in 2000, in line with population growth, lowered food prices, and increased incomes, to enable agricultural modernization and structural transformation (Hazell and Ramasamy, 1991). There were, however, some limitations. For example, the technology and targeted inputs relied on the availability of irrigation, even though 60% of agricultural land in India is dependent on rainfall. As a result, new technologies were not adopted uniformly across the country, exacerbating interregional and cross-household inequalities, and resulting in a singular focus on irrigated crops, fluctuating outputs, and environmental degradation due to poor land and crop management (Prasad *et al.*, 2007; Pingali, 2012). As a consequence, in the states of eastern India and semi-arid central India, agricultural development, income growth, and nutrition have lagged behind.

The PDS was initially established during World War II to address food security through rationing, and following the Green Revolution, it was tasked with distributing surplus grain (Mooij, 1998). Under the PDS, rice, wheat, kerosene, sugar, and edible oil were distributed to consumers through Fair Price Shops at subsidized prices. PDS encountered various challenges, including poor geographic coverage and escalating fiscal costs, and was ultimately deemed a failure (Ramaswami, 2002), with evaluations showing that it did not impact overall calorie intake in the country (Kochar, 2005; Kaushal and Muchomba, 2015). In 2005, measures were taken to improve the system's coverage, efficiency, and targeting (Dreze and Sen, 2013; Dreze and Khera, 2015). In states where the PDS restructuring was carried out successfully, it was found to have increased calorie intake and improved dietary diversity through income effects (Kishore and Chakrabarati, 2015; Rahman, 2015; Krishnamurthy *et al.*, 2017).

Policy and institutional support for staple crops relative to other crops, as exemplified by PDS, has crowded out traditional micronutrient-rich food crops, such as coarse grains and pulses, especially in the irrigated tracts of the Indo-Gangetic plains. Farmer incentives to diversify out of staple grains are limited, with the markets for non-staples characterized by high transaction costs, resulting in the decline in the per capita availability of pulses from 65.5 g per day in the 1960s to about 44 g in 2015 (Pingali, 2015). A nutrition-sensitive agriculture policy can create a level playing field for nutrient-rich coarse grains and pulses (Pingali, 2015).

Nutrition policy – a long road

Mechanisms to combat malnutrition in India over the years have taken the form of policy legislations and Mission Mode Projects (projects with a set timeline) under various ministries of the government. These include the National Nutrition Policy (1993), National Plan of Action (1995), National Health Policy (2002), National Nutrition Mission (2003), and National Health Mission (NHM) (2013), the latter delivering iron supplementation, antenatal care, and postnatal care. That a proliferation of initiatives has not made sufficient headway on nutrition may be a sign to rethink these approaches.

Perhaps the most notable food-based assistance program enabled by these various missions and policies is the Integrated Child Development Services (ICDS) program. The ICDS was launched by the Ministry of Women and Child Development in 1975 with the aim of providing nutrition services and education to children under 6 years of age and pregnant and lactating mothers, especially within disadvantaged social groups. In the early 2000s, evidence showed that the program's effectiveness in reducing child nutrition was limited despite being in place for more than three decades (Balarajan and Reich, 2016). An inter-ministerial group was constituted to restructure the ICDS. Reforms included: (i) increasing the number of *anganwadis* (village-level centers providing nutrition services to mothers and children), especially in remote areas; (ii) making food supplementation universal; and (iii) increasing ICDS' budget fourfold between 2004 and 2008 (Biswas and Verma, 2009). These changes led to the program being able to reach 67% of children under 6 years of age across India in 2013.

Another notable initiative has been the Mid-Day Meal Scheme (MDMS) under the Ministry of Human Resource Development. The MDMS was introduced in 1995 to address hunger among children aged 6–14. It was only in 2001 that the scheme was adopted by all states after the Supreme Court of India ruled it mandatory to provide cooked meals (with 300 calories of energy and 8–12 g of protein) to all primary-school children for a minimum of 200 days a year. The ruling also extended to the ICDS scheme, making the entitlement a 'right to food'.

Although MDMS has increased school enrolment and attendance rates (Dreze and Kingdon, 2001; Afridi, 2010; Jayaraman and Simroth, 2015), the impact of both ICDS and MDMS on nutrition outcomes is not clearly established (Pingali and Rao, 2017). Similar to the PDS, both for the most part have been staple grain-based safety-net programs that have not considered local tastes and preferences, or micronutrient requirements (Pingali *et al.*, 2017). Some studies have shown ICDS to have an impact on reducing malnutrition among girls (Jain, 2015). Mittal and Meenakshi (2015) found that villages benefiting from ICDS in eastern India saw an 11 percentage-point decline in the prevalence of underweight children. Singh *et al.* (2014) also found that in Andhra Pradesh, access to midday meals at school provided significant health gains in drought-affected regions.

New Policy Directions: Challenges and Constraints

Although policy measures to combat malnutrition in India have often been fragmented and uncoordinated, in recent years more comprehensive policies and programs have taken center stage, but with significant limitations. The National Food Security Act (NFSA) and the National Nutrition Strategy Mission are two notable examples. The NFSA was launched in 2013 to increase food and nutrition security by enabling access to quality food at affordable prices (Desai and Vanneman, 2015). The Act legally entitles 75% of India's rural population and 50% of its urban population to a minimum of 5 kg of staple food grains per person per month, at subsidized prices. The Act also aims to give financial support to pregnant and lactating mothers and free nutritional support to children up to the age of 14. Coordinated by the PDS, NFSA would increase PDS's coverage by 15–20 million people, resulting in 884 million beneficiaries. Again, however, the NFSA's focus on staple grains sidesteps the problems of micronutrient deficiencies and protein energy malnutrition. It has also thus far had limited coordination with other schemes and programs (Pingali *et al.*, 2017).

Long overdue, the National Nutrition Strategy is being formulated to achieve a *Kuposhan Mukt Bharat* or malnutrition-free India. Spearheaded by the Ministry of Women and Child Development in consultation with various advisory groups, the mission is tasked with mechanisms to address child malnutrition, especially in poorly performing states and districts (Government of India, 2017). It aims to reduce underweight (below –2 standard deviations) among children (< 5 years of age) from the current 35.7% to 20.7%, anemia among children (6–59 months) from 58.54% to 19.5% and anemia in women and girls (15–49 years) to 17.7% from 53.1%. Implementing this strategy requires governance reform, convergence between different departments of the state running similar or complementary programs and also effective ways of monitoring and evaluation. This is not the first attempt at a comprehensive initiative at tackling malnutrition. The National Nutrition Policy formulated in 1993 attempted to address micronutrient deficiencies, and also land reforms, income transfers, health, and food safety concerns, but fell short (Government of India, 1993).

A Nutrition-sensitive Agricultural Sector for India

The link between agricultural production and nutrition is a crucial one that calls for a nutrition-sensitive agricultural sector. While a traditional agricultural sector encompasses the production, distribution, and consumption of food, a nutrition-sensitive one also addresses intra-household distribution of food and individuals' absorption and intake of micronutrients (Pingali and Sunder, 2017). This framework (Fig. 17.2) acknowledges that people's nutrition status is shaped not only by their individual behaviors and nutrient absorption but also by their household's access to food quality, quantity, and diversity, as determined by household income and that household's access to diverse foods year-round (Pingali and Ricketts, 2014). This section analyzes India's progress and challenges within the various areas of the framework.

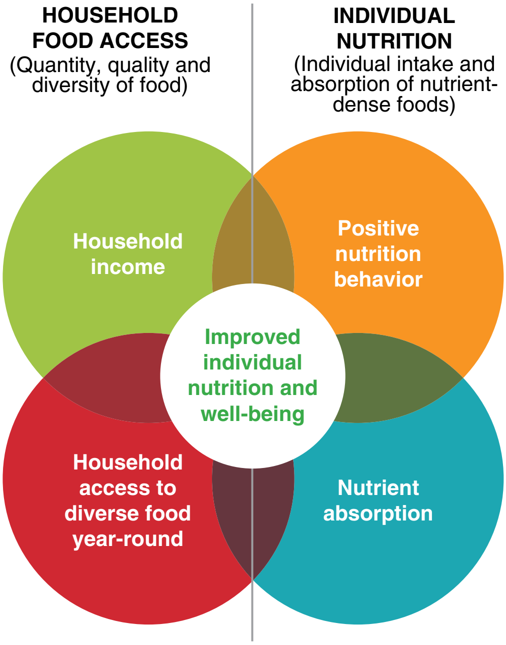

Fig. 17.2. Multisectoral pathways towards improved individual nutrition (adapted from Pingali and Rickets, 2014; license no. 4355620836211).

Household food access: quality, quantity, and diversity of food

Although household income determines the ability to access sufficient, nutritious food, the link between income and nutrition outcomes in India is not so straightforward. On the one hand, food producers are also net buyers of food; as such, food access is conditional on income (Gaiha *et al*., 2013). Most nutrients are also income elastic; therefore, a rise in income also increases nutritional intake (Pingali and Rao, 2017). However, while studies have shown that agricultural growth, as a proxy for income, has led to improvements in women's BMI, there is only a weak association with reduced child stunting (Ravallion and Datt, 1996). In states such as Kerala, Bihar, Himachal Pradesh, Tamil Nadu, Assam, and Tripura there appears to be a strong association, while in Gujarat and Madhya Pradesh, there appears to be a disconnect (Ravallion and Datt, 1996). The limited impact that income growth has on child nutrition in some Indian states can be attributed to the multidimensional nature of malnutrition (Jones *et al*., 2014; Snapp and Fisher, 2015).

Diversifying the agriculture sector can help it become more nutrition sensitive. Production diversity has been shown to have a positive impact on diet diversity (Herforth *et al*., 2012; Pingali and Sunder, 2017). However, as discussed earlier, India's disproportionate price and marketing incentives to major cereals have made diversification to pulses and coarse grains difficult. Diversification to animal husbandry, especially small ruminants and dairy, can also serve as an important source of income for smallholder farmers and the landless, considering the rising demand for meat. Although India has had successful dairy cooperatives, only a quarter of the volume of milk produced is marketed through the organized sector.

Linking smallholders to value chains may also improve nutrition, since the impact of production diversity on dietary diversity is often limited by poor markets (Berti *et al*., 2004; Bhutta *et al*., 2013; Girard *et al*., 2012). There has been a major drive in India to promote farmer producer organizations; since 2013, nearly 700 have been established, comprising 500,000 farmers. Although their impact on small farm production has not yet been studied, they could be a useful instrument in disseminating research and development (R&D) to close yield gaps and address climate resilience in coarse grains and pulses, and promoting biofortified, micronutrient-rich crops, such as iron and zinc pearl millet, zinc rice, and zinc wheat. The production and promotion of biofortified crops at the farm level is still in the nascent stages, however (Pingali *et al.*, 2017). The NFSA has provisions for fortified wheat to be distributed, and some states such as Gujarat, Rajasthan, and West Bengal have piloted its distribution (Bhattacharya *et al.*, 2017).

More and more, international trade is also playing a role in meeting the demand for nutritious foods. Traditionally, close to 60% of agricultural imports have been palm, soybean, and vegetable oils, but recent years have seen a surge in imported pulses, fruits, and vegetables. Effective distribution over and above availability would require PDS and ICDS to expand their services to include a more diverse food basket (Bhattacharya *et al.*, 2017). In some states, such as Karnataka and Tamil Nadu, millets are being provided by the PDS. In other states, like Chhattisgarh and Uttarakhand, the PDS provides pulses. This distribution should be expanded to other states, especially those lagging on key nutrition indicators.

Individual nutrition: intake and absorption of nutrition dense foods

Household-level access to food alone does not ensure nutrition security: intra-household allocation and the health environment are also critical factors. Traditionally, the allocation of food within the household has favored men and boys, leaving women and girls behind (Berti *et al.*, 2004; Pinstrup-Andersen and Watson, 2011). Addressing unequal control of resources and workloads, as well as access to water, sanitation, and hygiene, is essential to improve the nutritional status of women and children (see Chapter 6). Empowering women and improving the status of women is shown to have lasting impact on their nutritional outcomes and on the outcomes of their children (Case and Paxson, 2008; Almond and Currie, 2011). ICDS and the NHM have child- and gender-specific aims and priorities, but these are not integrated with empowerment initiatives. The NFHS-4 data show that stunting is more prevalent among children of illiterate mothers than among children of mothers with more than 12 years of education. It also shows that the prevalence of anemia among women decreases with more years of education. Education and behavior-change communication targeted to women thus needs to be integrated into existing interventions (Shankar *et al.*, 2017).

Water, sanitation, and hygiene also influence individuals' nutrition status and nutrition absorption. Studies have linked stunting and poor cognitive development to poor sanitation in early life and to the practice of open defecation (Case and Paxson, 2008; Almond and Currie, 2011). Access to clean water is also found to influence a variety of health outcomes, including child health and mortality (Desai and Vanneman, 2015). About half of the open defecation that occurs anywhere in the world takes place in India (UNICEF and WHO, 2017), and according to the NFHS-4 about 55% of the households surveyed reported to have members defecating in the open. It has become increasingly clear that toilet construction alone does not translate into toilet use. Initiatives such as *Swachh Bharat Abhiyan* (SBA), or the Clean India Campaign, that focus on the construction of toilets need to incorporate awareness and behavior change more fully.

Conclusion

India's slow progress in tackling hunger and malnutrition is of grave concern, revealing the challenge of meeting the UN's Sustainable Development Goal (SDG) 2 of eradicating hunger and malnutrition by the year 2030. To understand the nature and patterns of malnutrition in India, this chapter has analyzed the disconnect between the country's agriculture policies – focused on calories from rice and wheat production – and contemporary nutrition challenges. The preoccupation with staple grains permeates Indian institutions such as the PDS and major policies such as the NFSA (which does not address micronutrient deficiencies or protein energy malnutrition). It has also meant that regions that did not benefit from technologies of the Green Revolution era have shown poorer development and more severe malnutrition problems.

This chapter argues for a multidimensional, nutrition-sensitive approach to leveraging agriculture to tackle malnutrition. This approach requires policies and schemes such as the PDS, ICDS, NHM, and MDMS to integrate nutrition into all agricultural activities from production to consumption, while also addressing intra-household distribution of food, especially for women and girls, and individual absorption of nutrients. Diversifying the country's agriculture sector away from grains is essential to increase economic opportunities and improve the availability of micronutrient-rich foods. Interventions for empowering and saving time for women are crucial, as are interventions to ensure access to clean water, sanitation infrastructure, and good hygiene practices.

India has the largest number of malnourished children in the world, but the status quo can be changed. Neighboring Bangladesh has outperformed India in recent years, owing to its scale-up of health- and nutrition-related programs targeting women (Chowdhury *et al.*, 2018). A nutrition-sensitive agricultural approach can help the country achieve these same successes within a short period of time.

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A woman works in a maize field in Malawi. The country's agricultural policies are centered around maize production, limiting actions that could support more diverse diets. (ILRI/Mann)

18

Moving Beyond Maize: the Evolution of Malawi's Agriculture–Nutrition Policy Dialogue

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Introduction

In recent years, agriculture has been increasingly seen as a strong mechanism for addressing global malnutrition. More and more, agricultural actors in Malawi and beyond are under pressure to join hands with other sectors, including health, education, gender, finance and governance, and step outside of their traditional spheres of responsibility to take on nutrition-sensitive activities, or those with an indirect effect on nutrition outcomes. The need for multisectoral action has been largely embraced by nutritionists globally, and for the past decade or so efforts have been focused on bringing stakeholders from agriculture, as well as from other sectors, on board. While issue salience is important – agriculture actors recognizing their sector as important for improving diets and nutrition – only with thoughtful implementation of appropriate policies and programs might we see improved nutritional outcomes for the Malawian population.

Malawi is a low-income, food-deficit country with a high rate of chronic malnutrition: 37% of children aged 6–59 months are moderately or severely stunted (NSO and IFC International, 2016). Most of the population comprises subsistence farmers dependent on rain-fed agriculture, and 94% of the rural and 38% of the urban populations are engaged in agriculture, principally as smallholders with landholdings of less than 1 ha (NSO, 2012). Smallholder production is predominantly centered on maize, Malawi's main staple crop, which was grown on 80% of smallholder-cultivated land in 2011. Diets are dominated by maize, though household food consumption also includes a range of nutritious foods, but in inadequate amounts (Verduzco-Gallo *et al.*, 2014). Each year, some subset of the population requires emergency food assistance due to unfavorable weather patterns leading to production failures. Recent seasons have been particularly dire, with approximately 2.8 million people requiring assistance in the 2015–2016 lean season just before the following harvest and approximately 6.5 million people needing assistance in the 2016–2017 lean season (Government of Malawi, 2015b, 2017).

Learning from the Past: Factors Driving Multisectorality

Within the context of pervasive hunger and undernutrition, Malawi's agriculture sector is urgently concerned with ensuring sufficient calories for the population. Why and under what circumstances would it also take responsibility for broader dietary and nutrition objectives? Various country case studies have been undertaken to determine the factors that drive successful multisectoral collaboration for nutrition. Incentives for mobilization of the agriculture sector for nutrition could be financial, such as a coordinated funding stream for multisectoral nutrition activities, or organizational, such as helping collaborating institutions meet their own objectives (Garrett and Natalicchio, 2011; Mejía Acosta and Fanzo, 2012). Garrett and Natalicchio (2011) found that people-oriented leadership helped bring in partners and promote consensus. Mejía Acosta and Fanzo (2012) found that direct involvement of the executive branch at the presidential or prime ministerial level was critical. In addition to these factors, the framing of the issue should be relevant to the national agenda and speak to the specific objectives and priorities of the collaborating institutions.

This chapter examines the headway that has been made in Malawi in bringing the agriculture sector on board as a partner in addressing malnutrition multisectorally, and the factors that are driving progress. It also examines the challenges and gaps that remain both in framing the issue and moving from rhetoric to action.

Agriculture Policy in a Context of Chronic Hunger

In Malawi, as in many countries, agriculture-sector policies are chiefly focused on the production of staple food crops (Pingali, 2015); more specifically in Malawi, the production of maize. In the context of dependence on rain-fed agriculture and chronic hunger, food security is among the top concerns, and it tends to be understood narrowly as an issue of ensuring sufficient maize production. For instance, the primary indicator for the country's food-security status is maize production estimates. Due to its perceived importance to food security, maize is also at the center of agriculture policy and even influences electoral politics (Chinsinga, 2011; Mpesi and Muriaas, 2012). 'Maize is life', 'maize is food', and 'maize is politics' are common phrases among policy stakeholders and farmers alike (Smale, 1995; Chinsinga, 2011; Aberman *et al.*, 2018). In recent years, there have been two instances during which the president of Malawi acted as the de facto Minister of Agriculture, Irrigation and Water Development (MoAIWD, previously the Ministry of Agriculture and Food Security), first by President Bingu wa Mutharika in 2008 and subsequently by his brother President Peter Mutharika in 2017, further highlighting the national importance and politicization of the sector (Aberman *et al.*, 2012).

That agriculture policies and programs are heavily centered on maize is further exemplified by the role of government subsidies for inputs, known as the Farm Input Subsidy Program (FISP) in its current iteration. Promising a return to subsidized fertilizers in his 2004 campaign for election, President Bingu wa Mutharika implemented the precursor to the FISP to promote long-term maize self-sufficiency at the farm level (Mpesi and Muriaas, 2012). The aim of this precursor program was to enable people to grow and eat their own 'food', i.e. maize. The program was considered a major success by most, with Bingu being praised at home and globally for his role in increasing maize production to surplus levels, providing him significant political capital (FANRPAN, 2008; Dorward and Chirwa, 2011). However, many have argued more recently that the program's effects were not as strong or lasting as was hoped. Ex-post analysis suggests that estimates of production increases are likely inflated, targeting is inefficient, and benefits to households are largely limited to the current production season, making FISP an expensive program (Ricker-Gilbert and Jayne, 2011; Holden and Lunduka, 2013; Lunduka *et al.*, 2013; Pauw and Thurlow, 2014).

Despite its shortcomings, FISP comprises a major share of the agricultural budget. For instance, in 2008–2009, it accounted for 74% of agricultural spending (Ragasa *et al.*, 2016). In 2012–2013 and 2013–2014, it accounted for 58% and 44% of agricultural spending, respectively, fluctuating with global fertilizer prices and other factors. Added together with other agriculture programs that focus on maize, such as price supports for maize, agricultural spending is also aligned with the maize-centric approach to agricultural production and the perception of what constitutes food security in Malawi, in effect crowding out more comprehensive approaches to food and nutrition security.

Despite strong investment in agriculture, the country still faces periodic maize deficits and an annual need for food aid for the poorest Malawians. Thus, while the emphasis on staple food production is understandable in a setting where hunger is a pressing challenge, up to now this limited approach has not even yielded sustainable results for maize availability. While people's strong preference for maize in their diets is often cited by policy-makers as the reason for maize-centric polices, the political nature of maize in the country provides additional insights into why it is challenging to shift investment away from maize, even if there is will to do so. With poverty and malnutrition still at relatively high levels, despite some improvements, a more comprehensive approach to food and nutrition security is essential.

Rising Importance of Multisectorality and the Role of Agriculture

There has been a rising tide of attention to food security and nutrition more broadly, by development partners, researchers, and program implementers both in Malawi and globally, including an acknowledgement of the role that the agriculture sector plays in nutrition (World Bank, 2013). Furthermore, there is now better understanding of the virtuous effects of better nutrition on individuals' social and economic potential, and the synergies between healthy food systems and a strong agriculture sector (Government of Malawi, 2015a; Kanter *et al.*, 2015).

Central to multisectoral nutrition, the Scaling Up Nutrition (SUN) movement is a globally recognized effort to address malnutrition. Malawi joined the SUN movement as an 'Early Riser' in early 2011 (SUN, 2018). SUN functions largely as a convener of stakeholders, supporting information sharing and coherence in funding and action.

Building on the momentum of SUN and other initiatives, the International Food Policy Research Institute (IFPRI) convened a high-profile event in Malawi on 'Unleashing Agriculture's Potential for Improved Nutrition and Health' in September 2011. This conference partnered with the MoAIWD to discuss agricultural strategies that can promote improvements in nutrition and health.

Currently, all of the major donors and implementers of programs focused on nutrition or food security in Malawi tend to consider the issues of agriculture, food security, and nutrition as interrelated, and their programming reflects this viewpoint. For instance, the Government of Flanders and the Food and Agriculture Organization (FAO) of the United Nations (UN) supported 'Improving Food Security and Nutrition Policies and Programme Outreach' from 2011 to 2015, promoting education related to healthy diets for infants and young children through existing government mechanisms within the Ministry of Agriculture and Food Security/MoAIWD and the Ministry of Health (FAO, 2015). Flagship programs of the US Agency for International Development (USAID) have also focused on integrating nutrition into agriculture. In 2012–2015, USAID's 'Feed the Future Integrating Nutrition in Value Chains' program promoted the production and marketing of nutritious crops by smallholders (Mucha, 2015). Subsequently, USAID's 'Strengthening Agricultural and Nutrition Extension' program, which began in 2015, seeks to strengthen integrated agriculture and nutrition extension services (Cadrin and McNamara, 2016). In 2016, the Japan International Cooperation Agency launched 'Initiative for Food and Nutrition Security in Africa' to support African governments, including Malawi, to accelerate the implementation of their food and nutrition security policies on the ground and decrease malnutrition through nutrition-specific and nutrition-sensitive actions (JICA, 2016). These are just a few examples of integrated programming focusing explicitly on strengthening the agriculture sector's response to malnutrition.

Researchers have also focused on the potential synergies and missed opportunities between agriculture and nutrition in Malawi. As discussed in Aberman *et al.* (2018), there are challenges to undertaking this type of analysis with the available nationally representative data because of the 'data disconnect', wherein high-quality agricultural data are not available in the same datasets as data on individual diets, which is a key factor linking agriculture to nutrition (Gillespie *et al.*, 2012). Nevertheless, researchers have been able to examine household consumption as a precursor to diets of individuals, or use survey data collected from a smaller subset of the population to extrapolate to the broader population. Other analyses have focused on understanding the maize-first preferences of Malawians, and how the country's food and agriculture systems promote maize to the detriment of balanced and diverse diets. Aberman and Roopnaraine (2018) found that Malawians understand the value of diverse diets but cannot afford them, since they often have to sell nutritious crops to meet urgent cash needs. Gelli *et al.* (2017) found that food aid (provided to the country's food-insecure households each lean season by the Malawi Vulnerability Assessment Committee), made up primarily of maize and legumes, frees up resources so that households can consume other nutritious foods.

Other researchers have examined crop diversification and the quality of diets in Malawi. For instance, Snapp and Fisher (2014) found that FISP does not decrease crop diversification or household dietary diversity, but can actually support both by 'filling the maize basket' more efficiently, freeing up land to devote to other crops. Jones *et al.* (2014) found that crop diversification on smallholder farms increases household dietary diversity, though more so for wealthier households. Furthermore, providing nutrition education along with agricultural interventions to support the production of nutritious foods is even more effective for improving diets than agricultural interventions alone (Bezner Kerr *et al.*, 2011).

Analysis of dietary patterns by Pauw *et al.* (2018) showed that maize prices decreased and household food consumption increased between 2004 and 2011. However, during the same time period, the prices of leafy green vegetables increased and household food consumption decreased, suggesting that supports to maize production may be changing relative prices and, hence, dietary patterns.

Changing Tides or Shallow Pools?

Calls for the agriculture sector to play a greater role in coordinated efforts to improve nutrition, have influenced the policy narrative in Malawi. During the past decade or so, nutrition has become a salient issue among agriculture-sector actors and, importantly, within MoAIWD. The synergies between agriculture and nutrition are now widely acknowledged. Formal addresses by government representatives now commonly refer to nutrition-relevant concepts. Recently developed policy documents contain nutrition-sensitive language, such as the National Agriculture Policy approved in 2016 wherein one of the eight policy priorities highlighted is 'Food and Nutrition Security' (Government of Malawi, 2016). Another relevant example is the Agriculture Sector Food and Nutrition Strategy that was being formulated by MoAIWD at the time of writing. The strategy describes agriculture as the basis of food and nutrition security in that it has the primary role of feeding people well.

While the policy narrative and the content of policy documents reflect an appreciation for the responsibility of agriculture to improve nutrition, the extent to which investments in or implementation of government programs have incorporated multisectoral objectives is much more limited. This gap can be explained by weaknesses in incentives, leadership, and issue framing, all critical for successful multisectoral collaboration as previously discussed.

Conceptually, nutrition tends to still be primarily understood through a health-sector lens and secondarily as a multisectoral issue. In 2004, the Department of Nutrition, HIV and AIDS was established in the Office of the President and Cabinet to coordinate multisectoral actions, policies, and programs. It was led by Principal Secretary Mary Shawa, considered a strong champion for nutrition in Malawi. However, donor-supported public-sector reform moved the Department to the Ministry of Health in 2010 and cabinet reshuffling took Dr Shawa out of the Department entirely in 2012 (Babu *et al.*, 2016). The Department's move to the Ministry of Health is largely viewed as detrimental to multisectorality, reinforcing the framing of nutrition as a health-sector issue. Project implementers working within the nexus of agriculture and nutrition must typically choose a ministerial host for their activities, embedding their projects within either agriculture or health. Another disadvantage of this move is that the Department is no longer led by a principal secretary, diminishing its power to champion multisectoral action on nutrition. While SUN spearheads efforts to promote improvements in nutrition through multisectoral action, it is led by the Department in the Ministry of Health. Agriculture does not play a leading role therein, nor is it held to account for nutrition outcomes.

Agriculture-sector ownership and responsibility for improved diets and nutrition (or the mediating factors leading to nutrition outcomes) remains minimal in other ways. For instance, at the national level, Ministry leadership often delegates the Department of Agriculture Extension Services to engage in nutrition-related activities. Sidelining nutrition issues into one section of the Ministry reflects a narrow interpretation of agriculture's role in nutrition-sensitive action.

The understanding of what agriculture can or should be doing to support nutrition is currently restricted to a few specific concepts that fit easily into the existing policy narrative, such as diversification. Crop diversification is a common agriculture objective and is interpreted as being akin to diet diversification, a common nutrition objective. However, there are often misunderstandings about the subtle distinctions between the term as it is used in agriculture versus in nutrition. In addition, the causal pathways from agriculture policies and actions to impacts on nutrition are not often thought out or understood among agriculture-sector actors.

Harris (2017) describes the tendency for multisectoral groups to bring different interests on board through the use of buzzwords that are strategically ambiguous. This practice allows multiple actors to appear to be working in different ways towards the same collective objective, but underlying conflicts of interests and objectives may be masked. For instance, nutritionists promote diversification across foods or food groups based on their nutritional content, with the aim of increasing micronutrient intake. Conversely, agriculturalists may view diversification to be adding any new crops to a farm or production system, whether staple crops or cash crops, in order to diversify or enhance marketing opportunities and income. Thus, the implications of the two approaches could be very different, and the latter may not have any effect on diets if the causal pathways are not anticipated accurately. When nutrition stakeholders discuss the need to diversify diets through a more diverse agricultural system, agriculture stakeholders can easily agree to support crop diversification. But without explicit consideration of the causal pathways – if, for instance, crops are not nutritious and socially acceptable food crops – diversification may not have any effect on diet quality.

The narrative is slowly changing. Recently, in the wake of massive crop failures and humanitarian responses in 2016 and 2017, development actors developed a narrative described as 'breaking the cycle of hunger' in Malawi, such as was discussed in the IFPRI-led Compact2025 Forum that examined the barriers to ending hunger and undernutrition by 2025 (IFPRI, 2017). While this framing still incorporates the traditional agriculture-sector objective of feeding the people, it also brings in issues of food-system resilience, natural-resource management, and other cross-sectoral issues. Because it emphasizes reflection on what has not worked in the current set of policies, it has included a strong critique of maize-centric agriculture policies. This shift may represent an opening for a new and more effective set of approaches to nutrition-sensitive programming.

Conclusion

During the past decade, various stakeholders in Malawi – including donors, program implementers, and researchers – have successfully increased the salience of multisectoral nutrition, prompting the agriculture sector to recognize its important role in addressing undernutrition. This shift is evident in the current narrative used by agriculture actors, including within formal policy statements and documents. However, effective implementation of nutrition-sensitive programming by the MoAIWD has lagged behind the rhetoric. Exploring the challenges related to leadership, issue framing, incentives and political will could shed light on why and provide lessons for other countries engaged in a similar process.

Malawi lacks high-level nutrition champions who can engage in political debates on the country's priorities. Currently, responsibility for advancing nutrition within the health and agriculture ministries lies largely in the hands of director- and deputy director-level staff who have limited ability to influence national priorities and limited power to advocate for nutrition. Thus, while nutrition enjoys issue salience and improved implementation by donors, international organizations, and civil society, there is little political progress on shifting public investment away from maize support to make room for a more comprehensive approach to food security and effective nutrition-sensitive agriculture programming.

Looking ahead, there are many promising approaches that could be more strongly emphasized in agriculture programming, and could be considered low-hanging fruit for the agriculture sector. These include:

- A stronger emphasis on production support – including inputs and extension services – explicitly for nutrient-dense foods, especially traditional and wild foods.
- Improving market infrastructure such as storage and transport facilities for highly perishable products and for products susceptible to aflatoxin contamination.
- Decreasing seasonality of some nutritious foods by, for instance, introducing varieties of tree fruits with varied growing seasons and supporting irrigation for home vegetable gardens.
- Providing better management of small livestock to facilitate the use of manure for soil fertility and decrease negative effects of children's exposure to zoonotic diseases.

The Department of Nutrition, HIV and AIDS, the convener of SUN, serves as an active coordination body for promoting multisectoral nutrition. However, SUN is led by nutritionists and embedded in the health sector, with the MoAIWD lacking ownership and incentives for engaging in it. A more inclusive approach to leadership, such as placing the Department outside the line ministries, would facilitate cross-sectoral ownership. Furthermore, creating specific and concrete roles and responsibilities for different sector collaborators is important.

In addition, it is useful to ask how the MoAIWD benefits from active participation in multisectoral coordination meetings or even ultimately from improvements in diets and undernutrition, when its success is fundamentally judged by maize yields. Thus, determining how to incentivize the agriculture ministry's ownership of dietary and nutrition outcomes is critical. As mentioned previously, a funding stream managed outside the ministerial silos to support coordinated action may be an optimal solution (Mejía Acosta and Fanzo, 2012). Expanding the food security metric beyond maize yields would provide opportunities for non-financial incentives for MoAIWD.

The current narrative frames concepts such as diversification as central to nutrition-sensitive agriculture, providing an easy call to action for the sector. However, it also results in strategic ambiguity, masking the underlying conflict – or at least lack of cohesion – between the approaches and objectives of nutrition actors and agriculture actors. A reframing of the issue, such as the recent focus on 'breaking the cycle of hunger', could more effectively integrate nutrition and agriculture-sector objectives.

Ultimately, moving away from maize-focused investments and activities is politically challenging, especially given the dearth of high-level leadership and the political nature of maize security in the country. To some extent, debates about the technical challenges related to what the agriculture sector can and should be doing to better support nutrition may mask the underlying politics. Nevertheless, the salience of nutrition as a multisectoral issue and as a policy priority has increased among stakeholders and decision-makers in Malawi, and specifically within the MoAIWD. This success can be built upon, perhaps starting with a reframing of the issue to increase high-level support – thus paving the way for other actions – for a new approach to food and nutrition security in the country.

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A truck full of produce at a fruit market in Huai'an, China. Consumer demand for horticultural products is growing, prompting the government to invest in agricultural production technology and marketing. (Gwendolyn Stansbury/IFPRI)

19

China's Road to a Nutrition-driven Agricultural and Food System

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Introduction

During the past four decades, China has experienced market reforms that have transformed it from a centrally planned to a market-based economy, followed by rapid economic and social development. With the national economy growing at an exceptional annual growth rate of above 9% for three decades in succession, China has become the world's second largest economy and an upper-middle-income country (World Bank, 2018). Economic growth, accompanied by increasing agricultural productivity, raised 726 million people out of poverty between 1978 and 2016, with a concurrent decrease in the number of people considered food-insecure of 155 million since 1990 (de Brauw and Suryanarayana, 2015). Although the country has been able to supply adequate calories for its large population, it is still home to the second largest group of undernourished people in the world, with vulnerable populations such as women, children, the elderly, and migrants suffering disproportionately. 'Hidden hunger', the shortage of essential micronutrients, also affects millions of Chinese people (Chen *et al*., 2015).

The extraordinary economic boom in China has gone hand-in-hand with urbanization, a demographic shift promoted by the government. Whereas approximately 80% of the Chinese population lived in rural areas in 1980, 58.5% were urban residents by the end of 2017 (State Council Information Office, 2018). Rapid urbanization has been accompanied by rising incomes and a burgeoning middle class, resulting in a rapid shift in dietary patterns from grain-based diets to more protein-rich (meat and dairy) and diversified (fruits and vegetables) diets (Fan *et al*., 2014; Chen *et al*., 2015). Consumers are more and more concerned with the impacts of their diets on their nutrition and health. Region-to-region and urban–rural disparities in food and nutrition security are narrowing but still exist (Chen *et al*., 2014). While undernutrition remains a problem, there has recently been a significant increase in overweight and obesity rates, resulting from excessive intake of saturated fats, calories, and/or sugar. Chronic diseases highly associated with diets, such as diabetes, have also been on the rise (Chen *et al*., 2015).

With the above context in mind, this chapter discusses the linkages between agriculture, food, and nutrition in China. It begins with an overview of existing nutrition governance and policies, followed by a discussion of the major research progress on agriculture and nutrition links in recent years. The chapter then identifies gaps in current agriculture and nutrition policies, and provides policy perspectives on improving the agricultural sector for improving nutrition in China.

Nutrition Policies and Programs

Policy responses to the nutrition and health transition in China can be traced back to the release of the government's first *Food Structure and Development Outline* in 1993, followed by the *Food and Nutrition Development Outline* (2001–2010). Both of these policies served as overarching frameworks for setting national objectives for food consumption and nutrient intake. The latest outline, *Food and Nutrition Development Outline* (2014–2020), reflects an evolving understanding of China's food security and nutrition challenges and promotes diet diversity based on the daily food intake recommended by *Dietary Guidelines for Chinese Residents*. It aims to upgrade the current diet, heavy on starches and meat, to a balanced combination of cereal, meat, vegetables, fruits, milk, and soy (Fig. 19.1). The 2014–2020 Outline also cuts the recommended average daily intake of energy per person from 2600 kilocalories (kcal) in 1990 to 2200–2300 kcal. It is recommended that cereal should comprise 50% of these calories, while fat should represent less than 30%. The proportion of high-quality protein within the suggested daily protein category has increased from 33% in the 1990s to 45%.

China has recently placed public health at the center of the country's development, showing tremendous political will for health and nutrition. *Healthy China 2030*, approved by the Central Party Committee and the State Council in 2016, is the first national medium- to long-term strategic plan within the health sector. The plan calls for nationwide efforts to evaluate the nutritional content of agricultural products and foods and disseminate this information to broad audiences. The plan applies an approach based on nutrition assessment, guidance, and intervention, especially targeting vulnerable populations.

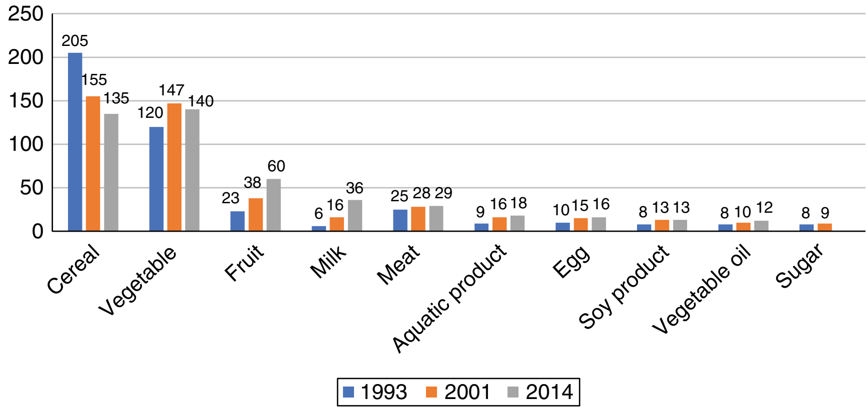

Fig. 19.1. Suggested annual food intake (kg) in three outlines.

In 2017, the *National Nutrition Plan (2017–2030)* was released, incorporating detailed nutritional goals, reasserting the necessity of existing nutrition programs, and proposing new interventions to help populations that suffer disproportionately from undernourishment, stunting, and micronutrient deficiencies (Table 19.1). Though progress has been made, current interventions still focus disproportionately on rural residents, especially infants and children (Xiang *et al.*, 2014), to the neglect of seniors and the urban poor.

The *National Nutrition Plan (2017–2030)* also proposes to promote nutrition research and strengthen monitoring and assessment of people's nutrition status, including intake of iodine, as well as ingredients in food products. It aims to better collect, analyze, and share national nutrition and health data through the current information system. Further efforts will be made to tailor dietary guidelines to the habits of different target groups and regions, following the *Dietary Guidelines for Chinese Residents* released in 2016, mentioned above.

The Chinese government is also beginning to pay attention to the importance of linking agriculture and nutrition through policy actions that could support a nutrition-enhancing food system. The *Food and Nutrition Development Outline (2014–2020)* mentioned above lays out the guiding strategy for working towards equal emphasis on food quantity and quality, coordination of production and consumption, and innovation. Measures will be taken to guide rational and nutritious food consumption, as well as foster a nutritional needs-driven food industry while conserving the distinctive features of local, traditional diets. The *National Nutrition Plan (2017–2030)* stresses the importance of producing nutritious and safe agricultural products, especially organic and pollution-free ones. It aims for green products and those indicating their geographic origin to account for over 80% of all agricultural products by 2030 (in 2014, they accounted for 40%). National-level demonstrative programs dedicated to research on nutritious staples, and vegetable and animal proteins, will lead the innovation on the production side. Research on minimizing nutrient losses during food processing, storage, and transportation is also championed.

Agricultural and food policies are also evolving to improve the country's nutrition outcomes, albeit with slow progress. China's *No.1 Central Document* is a significant policy document that outlines goals for the upcoming year, traditionally focusing on agricultural and rural issues. The latest version of the document aims to strengthen research on biofortification and food fortification technologies, in an effort to develop more nutritious foods. Other relevant agricultural policies, such as the *13th Five Year Plan on National Agricultural Product Quality and Safety Improvement* and the *13th Five Year Plan on Agricultural Technology Development*, also embrace nutrition as an objective of development strategies. They emphasize the evaluation of agricultural products' quality and nutritional attributes, as well as research on the impact of food processing, storage, and transportation on nutrients.

Table 19.1. Nutrition goals and interventions targeting vulnerable populations. Source: National Nutrition Plan (2017–2030); Fang, 2015.

Target population	Goals in *National Nutrition Plan (2017–2030)*	Existing and proposed national interventions
Infants (0–6 months) and children (under 5 years of age)	Raising breastfeeding rate to over 50% by 2020, and over 60% by 2030	*National Nutrition Plan* highlights the 1000 days of a child's life, from the beginning of a mother's pregnancy to the child's second birthday. Closely linked interventions will be designed to improve nutrition for pregnant women, support breastfeeding, and enhance the quality of nutritious supplementary foods
	Reducing anemia rate among children to under 12% by 2020, and under 10% by 2030 Cutting the prevalence of stunting among children to under 7% by 2020, and under 5% by 2030	*Nutrition Improvement for Children in Poor Areas* program was initiated by the National Health and Family Planning Commission (NHFPC) in 2012, to promote soybean-based and micronutrient-fortified Ying Yang Bao, an in-home complementary food supplement, to improve the nutritional status of children
Primary and middle school students	Reducing height difference between urban and rural students Reducing obesity rate among students Cutting the prevalence of stunting among rural students to under 5% by 2020	The Ministry of Education (MoE) and 14 other departments launched the *Nutrition Improvement Program for Rural Compulsory Education Students* in 2011 in a bid to address malnutrition among rural students by providing subsidized meals. It has so far reached 1590 counties in 29 provinces (State Council of China, 2017) China launched the *School Milk Project* in 2000 to ensure that students get safe, nutritious, and affordable dairy products in schools through the support of all levels of government. By 2017 the project has covered 20 million students across 31 provinces
Pregnant women	Reducing folic acid deficiency of pregnant women to under 5% Reducing anemia rate among pregnant women to under 15% by 2020, and under 10% by 2030	*Improving Nutrition, Food Safety and Food Security for China's Most Vulnerable Women and Children* (CFSN) was a 3-year (2009–2013) partnership led by the World Health Organization in collaboration with seven other UN agencies, eight Chinese ministries, and over 20 institutions at the central and local levels. Interventions included providing low-cost Ying Yang Bao, raising food safety and nutrition awareness among pregnant and lactating women, and encouraging the national and regional governments to develop intervention plans and policies targeting food safety and nutrition issues for children
Elderly people	Reducing anemia rate among elderly people to under 10% by 2020	Even though it is home to an aging population, China does not have a large-scale nutrition program targeting elderly people. Routine screening and assessment of nutrition status, and dietary guidelines for seniors are stated as a policy direction in the *National Nutrition Plan*
People in poor areas	Reducing anemia rate among poor people to under 10% by 2020	Health improvement is one of the major channels for poverty alleviation. Nutrition interventions, such as structural adjustment of agriculture and diets, will be incorporated into an anti-poverty strategy for the next stage

However, a guideline on enhancing the nutritional value of agri-food products, to be released as a result of this research, was mentioned only peripherally. Overall, it appears that the major agricultural policy documents still shy away from nutrition issues.

Agriculture–Nutrition Governance

Various sectors are involved in the work of improving nutrition in China. Nutrition has traditionally been the mandate of the former Ministry of Health, which reported directly to the State Council on its management of food quality and safety. In 2013, the Ministry of Health was dissolved and integrated into a new agency, the National Health and Family Planning Commission. Another key technical agency is the Chinese Center for Disease Control and Prevention (China CDC), which oversees the National Institute for Nutrition and Health, responsible for research on strategies and measures for food safety and nutrition. Technical support for nutrition is also offered by the Chinese Nutrition Society, a non-profit academic organization that provides official dietary and nutritional advice. The Society was commissioned by the Ministry of Health/ National Health and Family Planning Commission to develop the *Dietary Guidelines for Chinese Residents*. The Ministry of Agriculture oversees all agriculture-related issues.

In 1993, the State Food and Nutrition Consultant Committee (SFNCC) was set up to improve national coordination and planning of agriculture, food, and nutrition. Ex-or current senior officials of the Ministry of Agriculture typically chair the committee. The SFNCC tasks 31 experts from various fields, including agriculture, food, nutrition, health, economy, and trade, with coordinating national nutrition policies and interventions and accelerating improvements to address the underlying causes of malnutrition. The SFNCC's major achievements include developing the *Food and Nutrition Development Outline* and leading several nutrition interventions nationwide, such as the Soybean Action Program in the early 2000s, which met the needs of students for high-quality protein by providing them with soy-based foods.

In 2012, the Ministry of Agriculture launched the Institute of Food and Nutrition Development as an administrative and research body of SFNCC. The Institute is committed to: (i) carrying out research on food and nutrition strategies; (ii) coordinating food production, consumption, and nutrition; and (iii) improving Chinese citizens' diets. At the end of 2017, two other related structures came into existence: the National Nutrition and Health Steering Committee (as required by the *National Nutrition Plan (2017–2030)*) and the National Working Group on Nutrition Promotion (created to push the plan forward by the National Health and Family Planning Commission, Ministry of Agriculture, and the General Administration of Sport) (Xinhua Net, 2017). Since the National Health and Family Planning Commission has mostly led the establishment of these various new bodies, their interaction with the Ministry of Agriculture-led SFNCC remains to be seen in the long run.

Despite some positive outcomes, the government has run into difficulties in designing multisectoral mechanisms and policies to link agriculture and nutrition. Coordination failures continue to occur. Given that the SFNCC is an advisory body whereas the decision-making power remains in the hands of both the Ministry of Agriculture and the National Health and Family Planning Commission, the SFNCC lacks the authority to facilitate and monitor intersectoral policies and actions. Though the SFNCC is composed of members from various ministries and agencies, the majority of its members are ex-officials and no one is intuitively in charge. The responsibilities of different parties under such coordination are unclear.

Weak vertical coherence among agriculture and nutrition authorities and institutions at the central and provincial levels is another challenge. Most provinces do not have institutions dedicated to nutrition research or policy-making. Improving nutrition does not affect the political career of local leaders, resulting in a disconnect between high-level policies and practices on the ground.

Major Initiatives for Linking Agriculture and Nutrition

Though having long occupied separate silos with little consideration of their impacts on each other within the policy arena, agriculture and nutrition are in fact tightly wedded. The purpose of agriculture goes beyond growing crops and livestock as raw materials: it also includes the cultivation of well nourished people and the momentum for economic growth. On the reverse side, the costs of agriculture-related nutrient deficiencies are massive, mainly due to loss in human capital and productivity. In China, this cost was estimated to be 362 billion yuan (US$57.65 billion) in 2002, accounting for 4% of the GDP (Chinese Association for Student Nutrition and Health Promotion, 2008). Since China's agriculture sector is still dominated by approximately 200 million smallholder farmers (National Bureau of Statistics, 2017), agricultural development can lead to higher incomes, which can be used to purchase more food, higher-quality food, and a more diverse diet. Improved agricultural practices, such as increasing the production of vegetables rich in micronutrients, can also have positive impacts on the nutrition status of farmers, as shown by some successful interventions (Chen, 2013; Yang and Jiang, 2013).

A substantial body of literature has emerged around recent agricultural practices in China, yielding insights on how progress in agriculture can translate to improved nutrition status and economic benefits. There are two major ways in which agricultural production can contribute to enhanced nutrition. The first is through production diversity, which enhances access to a diet rich in not only necessary nutrients but also other important components such as fiber (Frison *et al*., 2011). China has long produced a diverse range of food crops of major global importance, including rice, wheat, soybean, potato, sweet potato, millet, and yam (Kell *et al*., 2015). However, agrobiodiversity in China is under threat due to land-use changes and the rapid adoption of hybrid varieties of some of the main crop types. Conservation of agrobiodiversity (see Chapter 4) is promoted in the country's *National Biodiversity Strategy and Action Plan*, which has been translated into provincial action plans (Wu *et al*., 2015).

The unstable market of cereals (rice, wheat, and maize), especially during the 2008 food crisis, prompted Chinese leaders to strategically release the country's stocks of grains, in order to buffer the price shock and protect people from malnutrition (Jensen and Miller, 2008; Yang *et al*., 2008). This scare and other factors led the country to further diversify into other crops. Potato, for example, has high nutritional value and provides a good supply of high-quality protein. China has significantly scaled up potato production and is aiming to dedicate 6.66 million hectares for potato production by 2020, 30% of which will be varieties that are suitable to produce food staples. The crop is set to become the nation's fourth food staple after rice, wheat, and maize.

The second key route through which agriculture can benefit nutrition is by increasing the production of highly nutritious foods, with an aim of benefiting either the general public or groups with specific nutritional deficiencies. In the case of staple crops, one way to enhance nutritional value is through biofortification whereby micronutrients are bred directly into staple crops through conventional methods or transgenic techniques (see Chapter 5). Since the introduction of biofortification in China in 2004, studies have been conducted by various institutions to explore crops fortified with zinc (Zn), iron (Fe), and folic acid (Jiang and Zhang, 2015; Li and Shou, 2015; Xie *et al*., 2016). After a decade-long effort by over 100 domestic scientists and international collaborators, the national biofortification program, called HarvestPlus-China, has achieved initial success. Enriched rice, wheat, maize, and sweet potato with bioavailable Fe, Zn, and vitamin A have been developed, and some of these have been approved for field dissemination (Lei, 2014).

Studies indicate the high cost-effectiveness of biofortification programs. With RMB 1 yuan of investment, the biofortified iron-rich wheat project of HarvestPlus-China could gain benefit of RMB 1118–1940 yuan over 30 years. This rate takes into account the low recurrent costs and significant health benefits that are achieved by reducing the disease burden of iron-deficiency anemia by at most 23.6% as measured by disability-adjusted life years (DALYs) (Li and Zhang, 2016). The positive health impacts of biofortified β-carotene-rich sweet potato have also been demonstrated among young beneficiaries, whose vitamin A deficiency was reduced to a 63.3% effective rate, compared with 42.9% in the control group fed with ordinary potato (Zeng *et al*., 2008).

An alternative to biofortification is agronomic fortification whereby inputs such as fertilizer are used to boost the micronutrient content of the crops. Cost-effectiveness analyses show that agronomic fortification of rice and wheat via foliar spray is an effective pathway to help populations relying on wheat within their diets to achieve 75–100% of their recommended Zn intake and decrease the health burden of Fe deficiency by 28% (Zhang *et al*., 2017; Wang *et al*., 2016).

Food fortification can enhance the micronutrient content of staple foods that are subject to some form of processing, as well as prepared foods. The Chinese government has established a regulatory framework, financed research and development (R&D) in the field, and promoted fortified foods. The government's commitment to food fortification is documented in several existing national plans, dating back to the *National Plan of Action for Nutrition* issued in 1997, which includes two provisions on micronutrient fortification. The *Food and Nutrition Development Outline (2014–2020)* calls for the acceleration of food fortification and regulation of nutritional fortification substances as well.

In line with this commitment, several fortification projects have been launched since the 1990s. China has made it mandatory for all edible salt in the country to be iodized according to the national standards from 1995, successfully expanding the household coverage of iodized salt to 95.3% in 2011. Surveillance data suggests that iodine intake of school-aged children (239 μg/l, measured by median urinary iodine concentration), taken as a proxy for the general population, exceeded the global target in 2011but needs to be brought back into the optimal range (100–199 μg/l) (Sun *et al*., 2017). Other major staples and condiments, such as rice, wheat flour (Huo *et al*., 2011; Sun *et al*., 2008), cooking oil, and soy sauce, also serve as vehicles for micronutrient fortification. Biofortification and food fortification are key strategies for improving nutrition in China, but the diversification of food production away from staple crops, as mentioned above, may be more critical in the long term.

Major Challenges That Need to Be Addressed

Despite increasing efforts from policymakers to link agriculture and nutrition in China, there are still a number of challenges that must be addressed.

1. Consumer demand for healthy and high-quality foods is still not being met. A recent study indicates that consumers are turning away from unhealthy foods, as evidenced by declining consumption of staple foods and a growing appetite for a diversity of foods of high or superior quality (Zhou *et al*., 2012). Yet the current food security strategy in China still largely focuses on boosting agricultural outputs to fuel economic growth and feed the entire population. While such efforts have led to tremendous gains in food production, especially in high-yield staple crops, nutrition still receives limited attention.

2. Activities along the agricultural value chain often have negative effects on nutrition. The links between agriculture and nutrition do not stop at the farm gate. Instead, agricultural products are stored, processed, distributed, retailed, and consumed in a range of ways that could affect their nutritional quality. Nutrient loss during processing, storage, distribution, and preparation due to spoilage, adulteration, inappropriate handling or preparation methods that introduce salt, sugar, fat, colors, and additives deserve more attention. The food and beverage processing industry is the largest user of sugar in China, accounting for 77.7% of the total consumption in 2007 (French and Crabbe, 2010).

3. Significant technological gaps still exist between China and other major international producers, particularly within the fields of biotechnology and integrated crop management for nutritious products. The country's innovative capacity for improving nutrition is limited by a lack of human capital, facilities, and financial support, and the adoption rate of advanced and sustainable technologies is low due to high costs and low provision of extension services. Though China's public R&D expenditure on agriculture has been growing quickly in recent years, its agricultural R&D intensity (R&D expenditure as a percentage of GDP) was only 0.63% in 2015, lower than the 1% suggested by FAO (Fan *et al*., 2017).

4. There are currently no clear linkages between agriculture and nutrition interventions carried out in the country. China still lags behind when it comes to designing agriculture–nutrition interventions with cross-sectoral benefits. Agriculture interventions lack explicit goals of addressing malnutrition and, likewise, nutrition programs' lack of consideration of upstream agricultural activities often raises concerns over food safety and program sustainability. It is also difficult for local rural economies to benefit from such interventions.

5. There is poor public awareness of nutrition issues. Studies on people's nutrition-related knowledge, attitudes, and practices indicate that, although some possess good attitudes toward nutrition and nutrition education, and show a willingness to improve their dietary behaviors, ordinary Chinese residents lack basic nutrition knowledge, as well as an awareness of nutrition-related diseases (Jia *et al.*, 2010; Guo *et al.*, 2015; Qi *et al.*, 2015). Gaps in public health and nutritional awareness lead to unhealthy food-consumption patterns across all age groups (Zhang and Sun, 2008; Guo *et al.*, 2015).

Policy Options for Linking Agriculture and Nutrition

Although China has benefitted from ongoing agricultural and economic success associated with significant improvement of food security, it remains burdened with nutritional challenges and complex gaps between agricultural production, consumption, and nutrition. A number of researchers have highlighted the fact that the availability and affordability of diverse and nutritious crops necessary for healthy diets has been neglected, and that the agriculture sector should consider how the food it produces translates into good nutrition and better health (Xu *et al.*, 2008; Wan, 2014; Chen *et al.*, 2015).

Looking ahead, there are a number of policy actions that China can take to establish and strengthen the linkages between agriculture and nutrition.

1. The country needs to introduce nutrition laws and regulations. Efforts to promote public health and nutrition status in China through legal mechanisms began in the late 1980s, but have since been held up (Zhai, 2012). As the importance of nutrition security becomes clear, lawmaking has returned to the forefront. For example, the draft *National Nutrition Improvement Act*, expected to be approved soon, will set nutritional targets for agri-food production, educate nutrition professionals, and ensure the sustainability of relevant policies and programs (Zhang *et al.*, 2011; Xu *et al.*, 2015). A multisectoral approach will also benefit from a sound legal framework which can articulate the government entity in charge of agri-nutrition coordination, as well as its composition, authority, and responsibility. Alongside these efforts, it is also critical to mobilize higher-level support for nutrition. For example, agri-nutrition coordination can take place under the office of president or prime minister, in order to hold participants of equal status accountable for their nutrition efforts (Levinson and Balarajan, 2013).

2. Nutrition-sensitive agricultural value chains should be promoted, as people's reliance on markets for satisfying their food and nutrition needs is bound to increase as urbanization continues (FAO, 2017). These efforts entail leveraging opportunities to enhance supply and/or demand for nutritious foods (such as fruits, vegetables, beans, fish) and identifying entry points to maximize nutritional benefits at every step of the chain, through actions such as biofortification, nutrient-preserving storage and transport, food fortification during processing, and nutrition signaling and labeling (see Chapter 3).

3. Investing more in nutrition-sensitive agricultural R&D is essential to advance the contribution of the agricultural sector to nutrition objectives. More attention should be paid to techniques for improving the nutritional quality, not just quantity, of agricultural products. Potential research areas include nutritious crop breeding, nutrition-enhancing cultivation, and nutrition-maintaining processing. The government can also improve regulations and policies to incentivize the private sector to increase its own investment in agricultural R&D, with options including the protection of intellectual property rights, tax concessions, and secured access to land.

4. Policy and program designers should adopt an integrated approach for inclusive nutrition interventions, particularly for those targeting vulnerable groups, including seniors and the urban poor, who remain in the shadows of large-scale programs focusing on infants and children. International lessons have provided several promising options, such as conditional cash transfer programs (Mohiddin *et al.*, 2012; Chen *et al.*, 2018). Some China-based projects have served as good examples for these types of interventions. *Improving Nutrition, Food Safety and Food Security for China's Most Vulnerable Women and Children* (CFSN), for example, promoted production diversification by supporting rural households to grow vegetables rich in iron and vitamin A, as well as to raise poultry and livestock, which had positive impacts on the lives of the poor, women, and children in western China (Chen, 2013; UNDP, 2013).

5. Efforts should be made to increase consumers' nutrition literacy for healthier dietary choices. Sound knowledge and understanding of nutrition is instrumental in guiding consumers' food choices towards healthy and nutritious products, which will not only improve individual health, but also open new markets for agricultural producers and incentivize them to produce high-quality agri-foods.

6. Finally, integrated strategies should be based on evidence. New insights on agri-nutrition links can be fulfilled by a robust food and nutrition monitoring and surveillance system, as proposed by the *Nutrition Improvement Work Management Approach* in 2010. Comprehensive, timely, and regularly collected consumption indicators such as caloric intake and dietary diversity are needed to formulate nutrition-focused agricultural strategies, while outcome indicators such as health and economic status should be tracked to indicate the impact and effectiveness of such strategies (Fan *et al.*, 2014; Chen *et al.*, 2015).

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A manager at an edible-oil processing factory in Tanzania poses next to a sunflower. Sunflower production has the potential to improve the livelihoods of smallholder farmers in the country. (Mitchel Maher/IFPRI)

20

The Way Forward for Nutrition-driven Agriculture

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This volume has highlighted the important links between agriculture and nutrition, both direct and indirect, both theoretical and practical. It has explored these relationships through various frameworks, such as value chains, programs and policies, as well as through diverse perspectives, such as gender. It has assessed the impacts of various agricultural interventions and policies on nutrition, including those that integrate behavior change communication or social protection, and profiled the up-and-down journeys of countries such as Bangladesh, China, Ethiopia, India, and Malawi in integrating nutrition into agriculture policies and program interventions. It has highlighted successes such as biofortification, the integration of behavior change communication and gender equality into existing agricultural interventions, and agriculture's role in improving household access to nutritious foods and diet diversity. It has analyzed challenges such as climate and environmental change, undernutrition, and obesity. And it has pondered big questions, such as how to build capacity, engage with the private sector, participate in the big data revolution, and foster strong governance and leadership throughout agriculture and nutrition.

The volume has conveyed that we know far more about the ways in which agriculture and nutrition interact than we did just 5–10 years ago, when interest in the agriculture–nutrition nexus began to really take off. More and more nutrition-driven agricultural programs are well designed, and the evaluations of their impact are more rigorous, relying on superior sample sizes and data analysis approaches, as well as clearer program impact pathways. Policy makers are also paying more attention, and devoting more policy space, to agriculture and nutrition. Whether this rhetoric translates into action remains to be seen in many low-income countries.

Despite the wide range of issues and perspectives appearing in this book, several strong themes emerge that provide interesting insights on how to move agriculture–nutrition forward in the coming years.

Start with Clear Nutrition Goals

It may seem obvious that in order to achieve truly nutrition-driven agricultural policies, programs, investments, and strategies, we need to explicitly integrate nutrition into their design. Yet many 'nutrition-sensitive' agricultural interventions or policies do not use clear, measurable nutrition goals as indicators of success. 'Nutrition driven' sends the clear message that nutrition outcomes are being proactively included as explicit goals of agricultural programs and interventions. These outcomes include changes in anthropometry, improved micronutrient status, increased dietary diversity, and/or increased consumption of nutritious foods. Relevant, nutrition-friendly goals also include achieving gender parity in decision-making power over agricultural resources and household income. In this latter case, the impact pathways to nutrition – and to reaching, benefiting, or empowering women – need to be clear and quantifiable (with this reasoning applying to other types of interventions as well, such as social protection, as described by Gilligan in Chapter 10). Simply having women participating in a program does not necessarily lead to nutrition outcomes, and even when women do benefit, they are not necessarily empowered (Chapter 6). Within nutrition-driven programs and policies, nutrition is not merely an afterthought, but rather, a primary, strategic goal.

Move Beyond Staples

Many agricultural policies in high- and low-income countries were originally designed to address undernourishment, in terms of energy intake, and food security in emergency settings. As a result, national policies tend to favor the production of staple foods; for example, wheat and rice in India (Chapter 17) and maize in Malawi (Chapter 18). In countries such as Bangladesh, the price fluctuations for non-rice crops are much larger than for rice, indicating a high level of market-induced risks for farmers attempting to move out of staples (Chapter 15). Agricultural policies also make nutrient-dense foods such as animal-source products, fruits, and vegetables cost-prohibitive for poor households to both produce and consume. In fact, the high expense of nutritious foods for the poor provides perhaps the best reason for nutrition-focused agricultural development since 'other economic sectors may well drive income growth, but only food policies can influence the affordability of nutritious foods' (Chapter 2). Reducing or eliminating agricultural distortion policies can be a step forward in lowering the costs of nutritious foods. But agricultural subsidies often also have a social protection aim to them, since farmers make up a large share of the poor population (Chapter 8). Thus, any policy shift to eliminate distortions should be accompanied by equal measures to ensure that poor agricultural households are not left behind. One option is to shift the focus of agricultural subsidies to support the production, processing, transportation, and marketing of nutritious foods. This support can come in the form of increased research and development on nutrient-dense crops, higher investment in infrastructure underlying the value chains of non-staple foods, and income support to poor and vulnerable farming households growing these crops.

Include the Minimum Package in Any Intervention

Nutrition-sensitive agricultural interventions are especially effective when they include behavior-change communication and can even improve child nutrition outcomes such as dietary diversity, nutrient intakes, anemia, diarrhea, and wasting when they integrate health-seeking and water, sanitation, and hygiene practices, or provide fortified products in areas where it is difficult to access nutrient-rich foods (Chapter 9). Thus, agricultural programs seeking to ensure an impact on nutrition should consider, at the very minimum, integrating three components: (i) strong behavior-change communication; (ii) activities that empower women but also promote gender equality within households and communities; and (iii) the provision of micronutrient-fortified products targeted to children and pregnant women. In Senegal, for example, a dairy value chain project distributed micronutrient-fortified yogurt as an incentive to female dairy farmers for increasing their milk production. The strategy was coupled with behavior change communication on infant and young child feeding. An evaluation found that children of participating farmers who received both behavior change communication and the fortified yogurt had greater increases in hemoglobin than the control group that had received just behavior change communication (Chapter 6).

Be Prepared for Unintended Consequences

Nutrition and agriculture interventions and policies are implemented in the real world. Oftentimes, evaluations reveal unintended impacts after the fact. For example, implementing agricultural interventions to boost household income may unintentionally lead households to use that income to purchase commercially processed foods, raising the risk of malnutrition due to the consumption of obesogenic foods (Chapter 7). Including women in agricultural interventions can impact their time for child feeding and care (Chapters 6 and 9). Targeting a safety-net program to poor households may be effective in reducing poverty, but not in boosting agricultural growth (Chapter 10). In China, large-scale nutrition programs have focused on infants and children, leading to the unintended consequence of seniors and the urban poor being left behind (Chapter 19). Up to 30% of people aged 60 or older in China are malnourished (Peking University China Health and Retirement Longitudinal Study, 2017). In India, price and marketing support to staple-grain production has reduced farmers' incentives to grow nutrient-rich coarse grains and pulses, reducing the availability of these crops (Chapter 17).

It is for this reason that Raiten and Combs (Chapter 7) advocate for a systems approach to nutrition, through nutrition ecology, which can help program designers assess all of the different local factors that can affect targeted communities, including differences in household members' access to nutrition and health, women's time availability, land use and availability, crop responses, and more.

Capitalize on, Not Shy Away from, Large-scale Changes

The world is changing rapidly. Many countries are facing significant demographic shifts such as urbanization, rapid market transformation, and, as a result, rises in levels of obesity and other non-communicable diseases. Climate and environmental change threatens the stability and productivity of agricultural systems. It is up to the international development community and more so, to national policymakers, to capitalize on these changes, which will occur anyway, to reinvent food and agricultural systems to deliver nutrition outcomes. Actions in this regard can include leveraging longer rural–urban and peri-urban–urban value chains to promote the retention and increase of nutrition (Chapter 3) or tasking crop breeders to combine nutritional traits with environmental traits, such as tolerance to drought and salinity, as well as to seasonal availability, so that multiple benefits can be gained (Chapter 4).

Build Up Incentives

What is the incentive for an agricultural extension agent in Brazil to incorporate nutrition messaging into her daily workplan? What will prompt a mother of four living on $1 a day in Thailand to shift part of her household food budget to pulses instead of rice? What will entice a small private-sector seed company in Bangladesh to start offering zinc-biofortified rice seeds to farmers? (The answer to this real-life conundrum has been for HarvestPlus to both guarantee a market for a portion of the private-sector production and subsidize the price for any seed that the private-sector markets directly to farmers; see Chapter 5 for more).

The various actors in the agricultural system, and the institutions within which they carry out their work, need incentives to work across sectors and outside their comfort zones. The private sector needs to be incentivized to promote public nutrition goals – in Chapter 11, Haddad offers numerous examples of policy carrots and policy sticks that governments can deploy to align these incentives. Undoubtedly, the strongest incentive for the private sector is market demand for its products. Building consumer demand for nutritious foods can impact actors all along the value chain to shift their efforts toward promoting nutrition. As Allen *et al.* point out in Chapter 3, consumer demand can be built up by educating the public on the value of nutrition and health through information campaigns, or by adding 'visible value' to products such as labeling their nutrient composition or promoting their high quality standards to distinguish them from their competitors. When these efforts fall short, then public policy can play a role. For example, distortions against producing and consuming nutritious foods can be removed. Governments can also mount their own nutrition education campaigns, support research and development of nutritious foods, and invest in the development of the various components that make nutrition-driven value chains possible, such as rural roads, electricity, nutrition extension, and cold chains.

Governments themselves also need incentives. In Malawi, for example, the success of the Ministry of Agriculture, Irrigation and Water is measured by maize yields, not nutrition outcomes; thus, it is important to consider how agriculture ministries can be persuaded to improve diets and malnutrition (Chapter 18). Gillespie and Nisbett (Chapter 12) find that there is strong support among professionals working in non-health sectors for mandatory mechanisms for collaboration; many of these professionals want to promote nutrition but are lacking management support systems and incentives to do so.

Reconsider Old Assumptions

Breaking down and rebuilding an entire food and agricultural system may require shattering some old assumptions too. For example, does the singular focus on women within agriculture–nutrition interventions work? Malapit (Chapter 6) suggests that focusing on the relationship between women and men is more optimal. This approach is already being taken up in Bangladesh, where the government-led ANGeL project is training both male and female beneficiaries so that they can make joint decisions on agricultural production and marketing within their households (Chapter 15).

In another example, many proponents of multisectorality advocate for integrating nutrition interventions into agricultural programs. But does this approach run the risk of making cross-sectoral programs too burdensome and complex? Is true integration really necessary, or can co-locating agriculture and nutrition interventions, i.e. carrying them out within the same community, be just as effective (Chapter 9)? The answers to these crucial questions require more dedicated research.

Finally, are multinational companies, with whom there are high levels of distrust among the nutrition community, the only viable players in public–private partnerships on nutrition? Small- and medium-sized businesses in horticulture and aquaculture, for instance, can play a huge role in the global production and dissemination of affordable and profitable nutritious foods. Furthermore, there is a wide array of resources that can help reduce the risk of embarking on a nutrition-focused partnership with the private sector, including accountability measures, conflict of interest guidelines, and more (Chapter 11).

Don't Forget an Enabling Environment

In food and agricultural systems, the law can be a powerful tool for setting the 'rules of the game'. In China, for example, legal mechanisms to promote public health and nutrition have faced challenges since the late 1980s and are only now returning to the forefront of nutrition strategy (Chapter 19). The law can permeate all areas of nutrition. For instance, in order for biofortification to be truly scaled, it needs to be recognized among global normative and regulatory agencies (Chapter 5). Setting quality standards for locally produced food products, such as fortified baby cereals, can go a long way in building up trust in nutritious foods among local populations and reducing the price of a healthy diet (Chapter 2).

An enabling environment can have far-reaching effects. Policies on how to manage big data, including ensuring privacy, security, and clear ownership and regulating new technologies can yield standards that are jointly understood by different sectors and disciplines (Chapter 14). An enabling environment can also make capacity-building efforts possible, including providing channels for formal education focusing on agriculture–nutrition links, nutrition training for agricultural extension agents, and multi-sectoral research opportunities (Chapter 13). Implementers of Ethiopia's Agricultural Growth Program, for instance, have benefited from an enabling environment that has allowed them to focus the first year of their work on creating capacities to implement a nutrition-sensitive agricultural strategy (Chapter 16).

An enabling environment can also help develop markets, especially key when considering that market access is a consistent and large modifying effect of the impacts of agriculture on nutrition outcomes, particularly dietary diversity (Chapter 9). The supporting environment for markets can include building infrastructure, such as roads and energy (Chapter 3). The price of inaction in this area is great. For example, the lack of a supportive environment for market connectivity and cold chains in India has limited the agricultural sector's diversification to higher value products that can improve diets and incomes (Chapter 17).

But an enabling environment also goes beyond policies. It includes the effective communication of knowledge and evidence, political commitment, leadership, capacity, financing, and governance (Chapter 12). Strong governance is particularly important in the case of power imbalances, such as between governments and multinational companies. Leadership is also crucial. While individual nutrition champions are certainly needed, sustainable leadership may exist in *networks* of individuals that can be held accountable by those suffering most from malnutrition. Additionally, leadership *throughout* nutrition, agriculture, and food systems, including leaders working at the ground and executive levels, can collectively contribute to systemic leadership (Chapter 12).

And Finally, Fill Some Knowledge Gaps – and Then Fill Some More

Perhaps the most salient theme of this volume is the need for more evidence. High-quality research has already suggested what could possibly work for agriculture–nutrition. For example, integrating behavior change communication into existing agricultural interventions can make them more effective in impacting nutrition (Chapter 9). Research has also demonstrated the efficacy of biofortified crops such as iron bean and iron pearl millet in improving nutritional status (Chapter 5). And new findings suggest that agricultural growth may be more likely to reduce stunting in Africa than in Asia, because stunting in Africa is more closely associated with poverty, with farming, and with rural livelihoods (Chapter 2). Equally as important, there are indications that evidence is oftentimes utilized beyond the research community. For example, in Ethiopia, findings from the Demographic and Health Survey and various landmark publications such as *The Lancet* helped push policymakers to go beyond food production to address malnutrition (Chapter 16). Thus, it is time to collect far more knowledge and lessons.

More research is needed on the sustainability of agriculture–nutrition interventions: in the long term, do participants of integrated interventions maintain the practices they adopted or keep the assets they built up? More work is needed on how to scale up successes and at what cost. Insights are needed on the political economy of linking the agriculture and nutrition sectors together, including analyzing power dynamics among various stakeholders and interest groups. More research is needed on how to assess the success of interventions with outcomes that span disciplines (Chapter 9). Cost–benefit analyses of nutrition-sensitive agricultural policies are lacking. The evidence on the impact of food value chains also remains limited (Chapter 3). Region-specific evidence is also sorely needed. For example, studies that analyze the nutrition impacts of specific agricultural policies are mostly lacking for Africa and the Middle East (Chapter 8).

Closely tied to research is the need for high-quality data (Chapter 14). Most low- and middle-income countries, for example, do not document or publish figures on their expenditures on specific agricultural investments (Chapter 8). At the global level, data on production and pricing of horticulture is particularly scarce, a key challenge when considering the importance of fruits and vegetables for healthy diets. These are just a few examples of the wide gaps in knowledge within the agriculture–nutrition nexus and a call to action to researchers to begin closing them.

The Start of Something New

The many unknowns within the agriculture–nutrition nexus are exactly what make it the pre-eminent field to be in. This volume has highlighted the pockets of advances in research, policy, and programs around the world during the past 5–10 years. Looking ahead to the next 5–10 years is an equally exciting prospect. During the next decade, findings from recently-improved program evaluations are sure to reveal new insights on which nutrition indicators, agricultural interventions and policies can reasonably affect, for which household members, and how and why. Students graduating with theoretical and practical knowledge of the impacts of agriculture on nutrition will launch careers where they can conduct research, design policies, and implement programs that have far-reaching effects on nutritionally-vulnerable people. And communities themselves will find ways of holding leaders and various actors accountable for advances in nutrition. These positive developments can become a reality as long as we continue to invest in knowledge, people, and institutions going forward.

The agricultural and food system is at a crossroads. Pervasive malnutrition, compounded by new challenges such as climate change and urbanization, make the current system untenable. If diets have been radically transformed for the worse in just a decade or two, as seen in the global obesity epidemic, why can't they be transformed again for the better within another decade? Indeed, with continued commitment to the agriculture and nutrition nexus, we may soon finally break the cycle of malnutrition for this and future generations.

Reference

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Agriculture for Improved Nutrition

Seizing the Momentum

Edited by **Shenggen Fan**, **Sivan Yosef** and **Rajul Pandya-Lorch**

Agriculture's vast potential to improve nutrition is just beginning to be tapped. New ideas, research, and initiatives developed over the past decade have created an opportunity for reimagining and redesigning agricultural and food systems for the benefit of nutrition. To support this transformation, this book reviews the latest findings, results from on-the-ground programs and interventions, and recent policy experiences from countries around the world that are bringing the agriculture and nutrition sectors closer together. Drawing on IFPRI's own work and that of the growing agriculture–nutrition community, this book strengthens the evidence base for, and expands our vision of, how agriculture can contribute to nutrition. Chapters cover an array of issues that link agriculture and nutrition, including food value chains, nutrition-sensitive programs and policies, government policies, and private sector investments. By highlighting both achievements and setbacks, *Agriculture for Improved Nutrition* seeks to inspire those who want to scale up successes that can transform food systems and improve the nutrition of billions of people.

Key features:

- Investigates the latest evidence on the relationship between agriculture and nutrition.
- Includes insights from internationally renowned researchers.
- Presents data from real-world settings that is highly relevant to the challenges faced by developing countries.

This book is ideal for policy-makers, practitioners, and students working in agriculture, international development, and nutrition.