The role of pulses in sustainable and healthy food systems

John McDermott and Amanda J. Wyatt
International Food Policy Research Institute (IFPRI), Washington, DC

Address for correspondence: John McDermott, International Food Policy Research Institute (IFPRI), 2033 K Street NW, Washington, DC 20006. j.mcdermott@cgiar.org

Improving nutrition is a development priority, particularly in low- and middle-income countries (LMICs) in Africa and South Asia, in which there is a persistent burden of undernutrition and increasing obesity. Healthy food systems can play a necessary role, aligned with other multisectoral actions, in addressing this challenge. Contributing to improved nutrition and health outcomes through food-based solutions is complex. In considering the role that pulses can play in addressing this challenge, there are useful conceptual frameworks and emerging lessons. National food systems in LMICs provide limited diet quality. Foods for a healthy diet may be produced locally, but they increasingly rely on improved markets and trade. What might be done to transform food systems for healthier diets, and what role can pulses play? Food systems innovations will require a convergence of technical innovation with smarter institutional arrangements and more effective policies and regulations. In many countries in Africa and South Asia, pulses can make important contributions to healthier diets. Options for supporting pulses to make a greater contribution to healthier diets include increasing the efficiency of pulse supply chains, creating more effective public–private institutional arrangements for innovation, and establishing policies, regulations, and investments that are nutrition sensitive.

Keywords: pulses; nutrition; health; food systems

Trends in food system transformation and the dietary transition

Feeding future populations
The global population is predicted to increase from the current seven to nine billion by 2050. Almost all of the population growth will occur in low- and middle-income countries (LMICs), with the greatest relative increase in African countries. Two future demographic trends are critical to understanding the challenge of feeding the world: (1) populations will be increasingly urban, with the number of people in cities and large towns increasing faster than rural populations; and (2) people will be richer and will use their increased incomes to purchase food that requires more resources (e.g., land, water, energy) to produce.

The challenge of feeding future populations is contested. Some are concerned that crop yields, especially under climate change, will be inadequate to keep pace with demand for food, feed, fuel, and fiber. Others suggest that it should be much easier to feed the world in the future, given important technical innovations and increased capacity in LMICs. While there is considerable consensus that overall food supply can be met in the medium term, longer-term constraints to food supply, as well as more focal supply shocks due to natural resource constraints and humanitarian crises, will need innovative solutions. Furthermore, in a world with increasing competition for shrinking resources, sustainable food systems for healthier diets will need to meet the growing demand for more nutritious foods—some, like meat and vegetables, that have higher resource requirements—using sustainable methods that protect the environment.

Food system transformation
Finding these innovative solutions requires us to examine all elements of the food system. By food system, we mean all of the activities and actors
involved in the production, processing, transport, and consumption of food. In LMICs, food systems are undergoing rapid transformation.5–8 As countries develop, the share of agriculture in the gross domestic product (GDP) and in agricultural employment tends to shrink (with some notable exceptions in Africa south of the Sahara and Latin America, where employment in agriculture shrinks while GDP remains the same).8 There are important supply constraints. In Africa, rural populations are growing, albeit at a slower pace than urban populations. This has resulted in smaller farm sizes and continuous cropping with few inputs, resulting in soil degradation.9 In Asia, there has been much more intensification of cereal production through the use of fertilizer and irrigation, but, particularly in the western Indo-Gangetic plains of South Asia, current agricultural water use for cereal production is unsustainable.10,11

There have been rapid changes on the demand side. Food retail grew rapidly, beginning in the 1990s in East Asia (outside of Japan and China), South America, South Africa, and Central Europe. In the late 1990s and 2000s, the “supermarket revolution” arrived in China, Vietnam, India, and Russia, growing from 5% to 20% by the end of the 2000s.12 As Popkin observes, “There is a rapid growth of modern retailing and consumption of consumer packaged foods and beverages and the shift of the food value chain from traditional traders and retailers to one where supermarkets and food manufacturers directly source food from farmers and traders.”6

Dietary transition
While there is much focus on how many people need to be fed, an even bigger question is, What foods will people be eating? Globally, we are seeing dramatic shifts in dietary patterns. The changes are attributed to improved agricultural practices that have increased productivity, increased the diversity of foods, and reduced the dependency on seasonality.13 As caloric consumption has risen, the composition of diets has changed (Fig. 1).2 Rising income levels, urbanization, and globalization have changed the demand for different types of food.2,14 For example, in Asia, diets are shifting from a high proportion of staples toward lower proportions of staples and higher proportions of livestock and dairy products, fruits and vegetables, and fats and oils.14,15

In the next section, we review how food system transformation in LMICs can have positive and negative effects by exploring the links between agriculture, food, and health.

Links between agriculture, food, and health in the food system
Drivers of the double burden of malnutrition
Until recently, hunger and undernutrition in LMICs were considered to be the primary nutrition problems facing the international development community. By undernutrition, we mean underweight (low weight for age), stunting (low height for age), wasting (low weight for height and weakness),
and micronutrient deficient (deficient in vitamins and minerals). There has been significant progress in reducing the prevalence of stunting in LMICs over the past 25 years. However, slow and uneven declines, particularly in Africa south of the Sahara and Southeast Asia, and variable progress within the same country mean there is still important work for researchers and policymakers.\[16-18\]

What are the drivers of undernutrition? Multi-country analyses associate stunting with a range of drivers: food, health and sanitation, and gender and equity in the Smith and Haddad analysis of 116 countries, and assets, women’s education, and open defecation in the Headey, Hoddinott, and Park analyses of four countries in South Asia.\[19,20\] Figure 2, adapted from the Smith and Haddad analysis, demonstrates that food contributes a bit more than one-third of the total estimated reduction in the prevalence of stunting.\[19\] Food and agriculture are important but not the only elements of improving nutrition.

At the same time, the number of children and adults who are overweight and obese is rising in all regions and nearly all countries, including in LMICs. Some countries that have reduced undernutrition—like Brazil, China, and Chile—have seen rapid increases in the prevalence of obesity and related chronic disease.\[17,18,21\] There are 20 countries where high prevalence of the three forms of malnutrition—under-5 stunting, women of reproductive age with anemia, and adult overweight and obesity—overlap.\[17\]

Pathways and evidence for nutrition-sensitive agriculture

Investment in agriculture can drive both economic and human development. On average in LMICs, agriculture generates about 10% of GDP and employs about 45% of the total labor force.\[22\] There has been considerable effort to conceptualize the relationship between agricultural growth and nutrition by defining the causal pathways that connect the two.\[23-27\] Although the frameworks may differ in terms of definitions of the pathways or what factors they highlight, there are four broad areas common across all: (1) food prices; (2) income from agriculture; (3) consumption of own production, primarily due to market imperfections; and (4) factors linked to gender. There is a consensus that these areas linked to agricultural growth can influence nutrition and health through multiple pathways—directly and indirectly.\[26\] Figure 3 depicts an adapted illustration of the pathways presented in Gillespie, Harris, and Kadiyala.\[23,24\]

On the basis of such conceptual pathways, nutrition-sensitive agricultural programs have been designed to have specific nutrition goals and to integrate both agriculture and nutrition interventions (e.g., nutrition education and behavior-change communication) to achieve them.\[25\] In practice, nutrition-sensitive agriculture programs may or may not align with other types of interventions from other sectors, such as water, sanitation and hygiene, or health (e.g., immunization and promotion of use of community health services).
Consistent with what we understand to be the drivers of undernutrition, agricultural interventions alone cannot be expected to have positive effects on reducing stunting if they fail to consider inequalities that exist within households (gender biases, education) or within societal structures or aspects of public health, like water and sanitation.

There are many competing options for development investments, so strong evidence for likely economic returns and development outcomes and impacts can strengthen one option over another. The economic case has been well made for nutrition. Over the past few years, randomized controlled trials (RCTs) have investigated the evidence for a range of nutrition-sensitive agricultural interventions, such as biofortification and improved and diversified household food production. These studies have demonstrated improvements in diet quality, micronutrient intake, and women’s knowledge and empowerment by combining agricultural interventions, gender empowerment, and nutrition education.

**Nutrition-sensitive value chains in national food systems**

While these program interventions demonstrably improve nutrition, the ultimate goal is to transform national food systems to improve socioeconomic and health status sustainably. The concept of food system transformation is appealing, and there has been considerable emphasis on food system frameworks and analysis in recent years. Here, we focus on one food system framework, developed within the CGIAR Research Program on Agriculture for Nutrition and Health, that emphasizes demand and supply drivers of value chains and their sustainability, health, and economic outcomes (Fig. 4). This framework emphasizes consumption and demand drivers as well as supply drivers in value chains; includes diet quality as a common determinant of both under- and overnutrition; considers economic and health impacts tracked by intermediate outcomes; and includes both environmental and business sustainability outcomes—reflecting the growing importance of private sector actors for economic development. This framework builds on single production to consumption value chains—from agricultural inputs and production through distribution, processing, consumption, and waste management. These multiple value chains then combine into a food system within a dynamic economic, environmental, social, and political national context and consider multiple levels from local to global.

Food system strategies and plans are now considered in larger development efforts, globally and nationally. As LMICs develop, there is...
increasing complexity of food supply chains as food systems transform. Most of the value addition moves from primary agriculture to transport, processing, retailing, and other activities. In food system transformation, the private sector plays a greater role, and the role of the public sector shifts to enabling public sector investments and policies. There is also greater focus on influencing consumer behavior through marketing, behavior change communication, and nutrition education. Diet quality assessments of food systems need to consider both adequacy of macro- and micronutrients and moderation of sugar and high-density energy sources, salt, and fat consumption, all associated with overweight and obesity and diet-related non-communicable diseases (NCDs), such as diabetes.

To date, food system transformation in LMICs has had the most success in improving food security by increasing the supply while decreasing the prices of cereals and by increasing incomes for farmers and other actors along value chains for both staples and perishable foods. However, sustainable food system transformation cannot be achieved without paying greater attention to environmental impacts and more equitable human development.

A food systems approach is very useful for considering the role of pulses, given the multiple potential development benefits—nutrition, health, and environmental—that pulses can provide. In the next section, we explain these potential benefits in more detail.

### Pulses in future food systems

Pulses, members of the legume family, include varieties of dried seeds, such as dried peas, edible beans, lentils, and chickpeas. Globally, the per capita consumption of pulses is a relatively minor share of overall dietary intake (Fig. 1). One objective of the International Year of Pulses (www.IYP2016.org) was to increase pulse consumption by encouraging people to eat a 60- to 100-g serving of pulses at least three to five times per week (up to 15–25 kg per year). Per capita consumption of pulses is not widely measured. Total availability of pulses for food across countries ranges from approximately 2 kg per capita per year in high-income countries to 10–15 kg in middle-income countries, mostly in Asia and Latin America. For low-income countries in Africa that produce pulses, the estimates are likely to be

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**Figure 4.** Conceptual framework describing impact pathways of supply and demand side value chain interventions. Reprinted from Ref. 39.
similar, although production and trade data are less robust.

The proteins in pulses and cereals are complementary, meaning that together they provide adequate amounts of all the essential amino acids. Pulses also provide essential micronutrients. Pulse protein is a relatively large share of overall protein consumption in low-income countries, ranging from 10–35% in Africa and falling as incomes grow.

Rwanda, owing to high consumption of beans, has the highest share in Africa. In China and high-income countries, protein from pulses represent only 1–2% of total protein consumption. The country with the greatest pulse consumption is India. Protein from pulses represents 12.7% of total protein in the Indian diet.

Shifting consumer preferences have led to declining shares of pulse consumption. This is despite increasing evidence of the nutrition and health benefits of pulse consumption. At the same time, there are underlying pulse supply inefficiencies that reduce pulse availability and access. Table 1 shows the development of overall production and yields per hectare (ha) in 11 major pulse-producing countries and their principal pulse crops. Most of the increase in pulse production through improved pulse yields (doubling or tripling in the past 20 years) comes from high-income (e.g., Canada, the United States, and Australia) and non-India BRIC countries (Brazil, China, and Russia) but not from most LMICs.

Between 1965 and 2014, the population grew by 160% and pulse production grew by 76%, while cereal production—which grew by 266%—increased at 3.5 times the rate of growth of pulse production. More recently (from 1999 to 2014), according to FAOSTAT, pulse production has increased (45%) relative to cereals (38%) and population growth (24%).

Pulses that are traded globally are mainly dried peas and beans coming from Canada, the United States, and, more recently, Myanmar. Trade has increased less for chickpeas, lentils, and peas—whose prices more than doubled between 2006 and 2008. The increased prices for pulses contrasts with cereals. In Bangladesh, prices for non-staple crops (largely pulses, roots, and tubers) have roughly doubled while cereal prices have declined between 1975 and 1995. In India in recent years, there have been major price increases for both domestically produced pulses and imports of higher-value pulses, such as pigeon peas and lentils. For food processing, use of lower-priced dried yellow peas has dramatically increased in recent years in both India and China.

As can be seen from the trends in pulse production and consumption described above, there are large differences in the role of pulses in national food systems. These reflect important national and subnational differences in ecological potential, economic development policy and investment, and sociocultural practices. In the context of national food system transformation using the framework in Figure 4, we consider four key intervention areas where pulses can contribute.

Agricultural innovations to improve the efficiency and effectiveness of pulse production

As highlighted above, most improvements in pulse production efficiency and supply have occurred in high-income countries. There has been much less success in increasing pulse yields in mixed-crop smallholder systems in LMICs. However, there are a few examples of interventions that have improved yields and supply of pulses in smallholder systems.

Beans are an important component of Rwandan diets. In the reconstruction after the 1994 genocide, the Ministry of Agriculture, the Rwanda Agriculture Board, and the International Center for Tropical Agriculture (CIAT) developed and extended,
Table 1. Evolution of overall production and yields per hectare (ha) in the major pulse-producing countries and their principal pulse crops

| Country         | Yield (kg/ha) | Production (×1000 metric tons) | Principal pulse crops                                      |
|-----------------|---------------|--------------------------------|-----------------------------------------------------------|
|                 | 1980–1982     | 1990–1992                      | 2011–2013                                                 |
| Australia       | 888           | 1056                           | 1352                                                      | 228.2 | 1742.0 | 3050.0 | Beans, dry; broad beans; chick peas; cow peas, dry; lentils; lupins; peas, dry; pulses, nes; vetches |
| Brazil          | 455           | 505                            | 994                                                       | 2440.5 | 2624.4 | 3054.6 | Beans, dry; broad beans; chick peas; cow peas, dry |
| Canada          | 1516          | 1736                           | 2197                                                      | 248.7  | 824.6  | 5382.4 | Beans, dry; chick peas; lentils; peas, dry        |
| China           | 1256          | 1347                           | 1591                                                      | 6517.4 | 3,726.8 | 4541.4 | Beans, dry; broad beans; chick peas; cow peas, dry; lentils; peas, dry; pulses, nes |
| Ethiopia        | 0.0           | 0.0                            | 1522                                                      | 0.0    | 0.0    | 2580.9 | Beans, dry; broad beans; chick peas; lentils; peas, dry; pulses, nes; vetches |
| India           | 457           | 554                            | 635                                                       | 10,441.5 | 13,045.1 | 17,554.0 | Beans, dry; chick peas; lentils; peas, dry; pigeon pea; pulses nes |
| Myanmar         | 655           | 641                            | 1307                                                      | 414.8  | 547.9  | 5,061.9 | Beans, dry; chick peas; cow peas, dry; peas, dry; pigeon pea |
| Niger           | 222           | 113                            | 313                                                       | 273.3  | 343.9  | 1556.1 | Bambara beans; beans, dry; chick peas; cow peas, dry; peas, dry; pulses, nes |
| Nigeria         | 414           | 642                            | 1080                                                      | 615.7  | 1428.0 | 3866.8 | Cow peas, dry and pulses, nes                      |
| Russian         | 0.0           | 1365                           | 1372                                                      | 0.0    | 3080.6 | 2307.9 | Beans, dry; broad beans; chick peas; lentils; lupins; peas, dry; pulses, nes; vetches |
| Federation      |               |                                 |                                                           |        |        |         |                                                          |
| USA             | 1594          | 1813                           | 1917                                                      | 1551.2 | 1581.2 | 2030.7 | Beans, dry; chick peas; cow peas, dry; lentils; peas, dry |

Source: FAOSTAT data sets. Accessed August 15, 2016.
Notes: Pulses include FAO’s 11 categories of pulse types: dry bean, broad bean, cowpea, chickpea, pigeon pea, lentil, dry peas, Bambara bean, lupin, vetch, and pulses, nes. Pulses, nes is an FAO category that includes pulses that do not fit in any of the other 10 categories of pulses. Yield is calculated by dividing annual pulse production by area harvested and calculating the 3-year average in each period.

through a coordinated effort, new varieties of beans. Around 86% of farming households in Rwanda grow beans. The new varieties of beans yielded at least double the locally available alternatives. In addition, systematic efforts were made to increase the iron content of these new varieties to provide 50% of the daily iron requirements through a process called biofortification. These biofortified iron beans, as they are known, have already been adopted by approximately 30% of Rwandan bean-growing households. The Rwandan success story has depended on the critical performance of government and public institutions in breeding and distributing new varieties and delivering...
extension services, all supported by international research.

The challenge for increasing production and improving yields in smallholder farming systems in LMICs is in trying to support tens or hundreds of thousands (or even millions) of smallholders by integrating input supply, knowledge and practices, and access to output markets. Success in such integration has been achieved in some vertically integrated high-value crops for export markets and for milk marketed by cooperatives in India.\(^47\) For pulse production, one example of successful integration comes from India: the More Pulses (MoPu) initiative of Tata Chemicals and Rallis India.\(^48\) In selected states in India, Tata provides seeds, fertilizer, and other inputs; provides a knowledge package of agricultural practices; and offers farmers the opportunity to sell their pulses through two Tata brands, the Rallis and i-Shakti pulse supply chains.\(^48\) Often, farmers are able to use government grants for increasing pulse production to pay for the inputs. Initial experiences in MoPu intervention areas indicates that yields and incomes can double. There is potential to extend this integrated input–output approach to other countries, particularly for higher-value pulses, such as chickpeas.

Research can play an important role in opening up new opportunities for pulse innovation by smallholder farmers.\(^49\) Both new, higher-yielding and shorter-season varieties and good agricultural practices for integrating pulses into rice–wheat systems in South Asia or maize or other crop–livestock systems in Africa will be important. Such research has been relatively neglected but could provide good returns while also increasing food system sustainability by improving soil quality and water efficiency. Varietal development also needs to be more sensitive to food companies and their demands for particular traits, such as increased fiber, protein, and specific micronutrients.

Innovations in logistics, processing, and marketing of pulses

As food supply chains lengthen, there needs to be much greater investment in value addition beyond the farm. Innovations in logistics, storage, and handling will be similar to those for cereals, except that the volume of pulses is much smaller. Innovations in communication and institutional arrangements will be critical in networking small- and medium-size entrepreneurs that can link producer groups and food processors and retailers. At present, supply chains for pulses in LMICs cannot supply sufficient or consistent quantities of pulses, which limits the ability of food companies and retailers from developing and promoting pulse-based foods, whether processed or just graded and packaged. In India and China, medium and large food processors often use imported pulses, such as yellow peas from Canada, to assure sufficient supply in making noodles and other processed foods.

Shorter pulse supply chains serving small and medium towns will also be important. The inefficiencies of local millers in India have been highlighted by the economist G. Chandrashekar, along with calls for a systematic upgrading of milling infrastructure (personal communication with author). Overall, demand for processed...
(particularly convenience) foods will increase. There are opportunities for pulses to contribute to improving the nutritional and health quality of processed foods. In general, pulses provide more micronutrients than cereals and can naturally improve micronutrient levels with or without additional fortification. One key constraint to pulse-based foods is their long cooking times. Innovations to create more instant pulse-based foods will be critical.

Relative to cereals and soybeans, formulations for including pulses in processed foods are not widely developed or used in most countries. At present, many mothers in LMICs struggle to get sufficiently nutrient-dense foods to feed young children; there is a considerable market opportunity for pulses to be incorporated into complementary foods for young children. Another food processing demand that can be met with pulses is in the area of nutritionally complete foods to prevent and treat undernutrition in humanitarian emergencies. Currently, many of the emergency foods provided are based on groundnuts, but other pulses may provide a cheaper and aflatoxin-free alternative that could be produced locally.

Interventions to increase demand for pulses
In most low-income countries, lack of dietary diversity among the poor remains a critical development challenge. Nutrition education and behavior change communication have been effective at increasing the diversity of food consumed by mothers and children, especially when combined with homestead food production and integrated into community health services targeting women and children. Beans and other pulses are ideal for use in these homestead food production and consumption systems.

As noted, the expansion of demand for pulses was an important component of the International Year of Pulses. A number of marketing strategies have been employed, including branding, social marketing campaigns, and cooking contests. Marketing by private sector companies can be very effective. In India, the i-Shakti branding of pulses, dals in particular, by Tata is a good example of what is possible and could be further developed with improved supply chains.

In LMICs, efforts to increase demand through programs that buy and distribute local agricultural products have increased in recent years. The public distribution system (PDS) in India is the largest public food distribution system in the world. In some states, there are concerted efforts to include the purchase of pulses as well as cereals, in large part because pulses are acknowledged to have potential to address protein deficiency. In Africa, the World Food Program’s Purchase for Progress program seeks to source foods it distributes in Africa from smallholder farmers in the country or neighboring countries. The WFP is actively exploring expanding pulse purchases along with their more traditional cereal purchases. Other opportunities for demand-pull public purchases of pulses from smallholders include broader development programs (such as Ethiopia’s Productive Safety Net Program, which has modified the food baskets participants receive to include pulses), as well as more targeted school feeding and food voucher programs.

Enabling policies and investments
In most LMICs, relative to cereals, pulses have been largely neglected by policy makers and public investors. As noted above, yields and overall production have been much greater for cereals than pulses in the last 50 years. This has also been reflected in relatively lower consumer prices for cereals and increasing prices for pulses. The policy distortions underlying these cereal–pulse trends have been assessed in India. Policy instruments have included input subsidies for cereal producers (water, electricity, and fertilizer), increased public investments in breeding and agronomy of cereals relative to pulses and other crops, and price support through high support prices and procurement of cereals for public food distribution programs. Most of these policies were developed in the 1960s and 1970s to promote the Green Revolution goal of national food security in cereals and were very effective. In many other LMICs, policies and investments have focused on cereal production. However, now countries are expanding their policy goals from food to nutrition security and seeking to use agriculture to diversify diets and improve nutrition. This requires a rebalancing of policy and investment, described by Pingali as crop-neutral policies. In India, there are some moves to re-balance policies through increasing minimum support prices for pulses and including them in food distribution systems in some states. Increasing public investments in breeding and agronomy are also beginning.
but unwinding input subsidies for cereals is very difficult politically. Of particular importance will be reducing subsidies leading to the overuse of water in the western Indo-Gangetic plains. As more sustainable water-use policies become necessary, there will have to be a change in crops, and increasing integration of pulses would be an important component of such a strategy.

While agricultural policies are important, concerted efforts for improving nutrition and health through pulse consumption must engage and convince health policy makers. Public health investments focus on large health impacts, and, relative to other sectors, investment decisions are based on rigorous evidence from RCTs, meta-analyses, and systematic reviews. For example, in the Rwanda iron bean example, evidence was crucial for gaining cross-sectoral support from both agriculture and health ministries and from the Prime Minister’s office for investments in scaling up biofortification. Recent results from an RCT concluded that Rwandan women who consumed iron beans showed significantly improved iron status compared with women who consumed regular beans.55 This study is part of a growing body of convincing evidence that the common bean is a good vehicle for iron biofortification.56 The health evidence, combined with the promising yield data, has been packaged into a public awareness campaign that leverages the power of mass media and pop music stars to educate Rwandans on micronutrient deficiencies and the benefits of iron beans.57

One high-impact area that the health sector is increasingly interested in mitigating is the burden of overweight and obesity and diet-associated NCDs.58,59 This is a global problem and is increasingly important in LMICs where deaths due to NCDs are disproportionately increasing. In addition to the health burden, the economic impacts are enormous. In India, current health system expenditures are approximately 4% of the GDP, which could dramatically rise toward 10–18% of GDP levels in high-income countries if current obesity and NCD trends continue.60 There is a growing body of high-quality evidence on the potential for pulse consumption to moderate consumption and reduce obesity, including systematic reviews demonstrating health effects, such as reduced cholesterol, glycemia, and blood pressure.61–65 A focus on diet quality will be an increasingly important area of cross-sectoral intervention in LMICs in the future. Maharashtra and other Indian states are increasingly placing nutrition goals at the center of cross-ministerial action. A recently completed analysis from India noted positive albeit small investments, such as agricultural missions directed at pulses and inclusion of coarse grains and pulses into the PDS in some states and enabling trade policies—such as temporary removal of duty on import of pulses—that if combined and/or scaled up could help create a healthy food system in India.66 Greater emphasis on improving diet quality in health systems could accelerate this process.

Translating opportunities to actions

We have described a number of opportunities to enhance the contribution of pulses in improving nutrition and health through food systems and value chains in LMICs. However, translating these into actions and results will require cooperation and coordination between public and private actors and among multiple sectors—particularly food, agriculture, nutrition and health, and social development.

With economic development, the relative role of the private sector in food systems increases dramatically. In LMICS, most food is produced by smallholders, marketed for smaller-scale market agents, and processed by smaller enterprises, but public sector support is usually relatively large. With economic development, larger commercial companies play a greater role in the food system, and the public sector plays less of an active and more of an enabling and regulating role. Increasingly, large private companies consider both sustainability and health considerations along with their necessary emphasis on profit. This is the so-called triple bottom line of profit, planet, and people, which examines the company’s financial, environmental, and social performance over time. Beyond the imperative for sound business plans, most large food and food-processing companies have detailed social responsibility plans that address environmental sustainability. Social responsibility plans that include the provision of healthy foods are generally less common, but, as can be seen above, there are strong imperatives to consider health.

This linking of innovations for wealth, sustainability, and health has led to the concept of convergent innovation.67 As systems become more complex, convergence is important. A simple
example is the change in policy required to move from food security to consider healthy and sustainable diets. Jha et al. explored the role of pulses in food sector convergent innovation for improved wealth and health. They proposed projects in three priority areas—an innovation partnership for pulse-food innovations, coordinating pulse value chains for greater production efficiency from input supply through output market demand, and integrated rural agriculture–health investments, including pulses and vegetables to diversity diets.

Convergence will be critical for pulses to contribute to complex real-world problems. However, we have also identified some very specific actions for individual sectors and actors, in consultation with others. For example, pulse producers in LMICs need to improve the efficiency and effectiveness of pulse production (and thereby reduce and stabilize prices). More effective integration of pulses into mixed-crop systems is essential. The pulse sector, in consultation with the health sector, needs to align production to human health objectives, such as filling common micronutrient gaps and mitigating the risk of overweight and obesity and diet-related NCDs. Pulses can play an important role in evolving food systems in LMICs. Some of this will require broader cooperation to improve logistics, storage, and simple processing of pulses that can be aligned with similar requirements for cereals. Food processors need to innovate in the development of healthier processed pulse–cereal foods. Finally, we need to move beyond supply-side solutions to a greater understanding of food consumption trends. The pulse sector can play an important role in informing this transition, by building the evidence base and through effective branding and marketing. Because of their multiple benefits, pulses should play a more important role in future food systems. Concerted efforts by multiple actors will be required for this to be achieved.

Conflicts of interest

The authors declare no conflicts of interest.

References

1. United Nations (UN), Department of Economic and Social Affairs, Population Division. 2014. World urbanization prospects: the 2014 revision, highlights. New York: United Nations. Accessed February 13, 2017. https://esa.un.org/unpd/wup/Publications/Files/WUP2014-Highlights.pdf.

2. Food and Agriculture Organization of the United Nations (FAO), World Food Program (WFP) & International Fund for Agricultural Development (IFAD). 2012. The state of food insecurity in the world 2012. Rome: Food and Agriculture Organization of the United Nations. Accessed February 13, 2017. http://www.fao.org/docrep/i3027e/i3027e.pdf.

3. Harvey, F. 2013. Growth in crop yields adequate to feed the world by 2050—research. The Guardian. Accessed February 13, 2017. https://www.theguardian.com/environment/2013/jun/20/crop-yields-world-population.

4. The Economist. 2011. How much is enough? Special report: feeding the 9 billion. The Economist. Accessed February 13, 2017. http://www.economist.com/node/18200702.

5. Gómez, M.I. & K.D. Ricketts. 2013. Food value chain transformations in developing countries: selected hypotheses on nutritional implications. Food Policy 42: 139–150.

6. Popkin, B.M. 2014. Nutrition, agriculture and the global food system in low and middle income countries. Food Policy 47: 91–96.

7. The Government Office for Science. 2011. Foresight. The future of food and farming (2011). Final project report. The Government Office for Science, London. Accessed February 13, 2017. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/288329/11-546-future-of-food-and-farming-report.pdf.

8. World Bank. 2008. World development report 2008—agriculture for development. World Bank, Washington, DC. Accessed February 13, 2017. http://siteresources.worldbank.org/INTWDR2008/Resources/WDR_00_book.pdf.

9. Jayne, T.S., J. Chamberlin & D.D. Headley. 2014. Land pressures, the evolution of farming systems, and development strategies in Africa: a synthesis. Food Policy 48: 1–17.

10. Grace, P.R., M.C. Jain, L. Harrington & G.P. Robertson. 2003. The long-term sustainability of tropical and subtropical rice and wheat systems: an environmental perspective. In Special Issue on Improving the Productivity and Sustainability of Rice–Wheat Systems: Issues and Impacts. J.K. Ladha et al., Eds.: pp. 27–43. Madison: American Society of Agronomy, Crop Science Society of America, Soil Science Society of America.

11. Gregory, P.J., I.S. Ingram & M. Brklacich. 2005. Climate change and food security. Philos. Trans. R. Soc. Lond. B Biol. Sci. 360: 2139–2148.

12. Reardon, T. 2016. Growing food for growing cities: transforming food systems in an urbanizing world. The Chicago Council on Global Affairs. Accessed February 13, 2017. https://www.thecouncil.org/sites/default/files/report_growingfoodforgrowingcities2.pdf.

13. Kearney, J. 2010. Food consumption trends and drivers. Philos. Trans. R. Soc. B Biol. Sci. 365: 2793–2807.

14. Pingali, P. 2007. Westernization of Asian diets and the transformation of food systems: implications for research and policy. Food Policy 32: 281–298.

15. Keats, S. & S. Wiggins. 2014. Future diets—implications for agriculture and food prices. London: Overseas Development Institute (ODI). Accessed February 13, 2017. https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/8776.pdf.
16. Black, R.E., C.G. Victora, S.P. Walker, et al. 2013. Maternal and child undernutrition and overweight in low-income and middle-income countries. *Lancet* **382**: 427–451.

17. International Food Policy Research Institute (IFPRI). 2016. Global nutrition report 2016: from promise to impact. International Food Policy Research Institute, Washington, DC. http://globalnutritionreport.org/.

18. Tzioumis, E., M.C. Kay, M.E. Bentley, et al. 2016. Prevalence and trends in the childhood dual burden of malnutrition in low- and middle-income countries, 1990–2012. *Public Health Nutr.* **19**: 1375–1388.

19. Smith, L.C., & L. Haddad. 2015. Reducing child undernutrition: past drivers and priorities for the post-MDG era. *World Dev.* **68**: 180–204.

20. Heady, D., J. Hoddinott & S. Park. 2016. Drivers of nutritional change in four South Asian countries: a dynamic observational analysis. *Matern. Child Nutr.* **12**(Suppl. 1): 210–218.

21. Jones, A.D. & G. Ejeta. 2015. A new global agenda for nutrition and health: the importance of agriculture and food systems. *Bull. World Health Organ.* **94**: 228–229.

22. Food and Agriculture Organization of the United Nations (FAO). 2015. The state of food and agriculture—social protection and agriculture: breaking the cycle of rural poverty. Rome: Food and Agriculture Organization of the United Nations. Accessed February 13, 2017. http://www.fao.org/publications/sofa/2015/en/.

23. Gillespie, S., J. Harris & S. Kadiyala. 2012. The agriculture–nutrition disconnect in India: what do we know? IFPRI Discussion Paper. Washington, DC: International Food Policy Research Institute.

24. Herforth, A. & J. Harris. 2014. Understanding and applying primary pathways and principles. Brief #1. Improving Nutrition through Agriculture Technical Brief Series. USAID/ Strengthening Partnerships, Results, and Innovations in Nutrition Globally (SPRING) Project, Arlington, VA.

25. Ruel, M.T., H. Alderman, & Maternal and Child Nutrition Study Group. 2013. Nutrition-sensitive interventions and programmes: how can they help to accelerate progress in improving maternal and child nutrition. *Lancet* **382**: 536–551.

26. Webb, P. 2013. Impact Pathways from Agricultural Research to Improved Nutrition and Health: Literature Analysis and Research Priorities. Prepared for the ICN2 Second International Conference on Nutrition. Rome: Food and Agriculture Organization of the United Nations and World Health Organization. Accessed February 13, 2017. http://www.fao.org/3/a-as573e.pdf.

27. World Bank. 2007. *From Agriculture to Nutrition: Pathways, Synergies and Outcomes*. Agriculture and Rural Development Department. Washington, D.C.: World Bank. Accessed February 13, 2017. http://sitesources.worldbank.org/INTARD/825826-1111134598204/21608903/January2008Final.pdf.

28. Hoddinott, J., M. Rosegrant & M. Torero. 2012. Investments to reduce hunger and undernutrition. Challenge Paper, Copenhagen Consensus 2012. Accessed February 13, 2017. http://www.copenhagenconsensus.com/sites/default/files/hungerandmalnutrition.pdf.

29. Olney, D.K., S. Vicheka, M. Kro, et al. 2013. Using program impact pathways to understand and improve program delivery, utilization, and potential for impact of Helen Keller International’s homestead food production program in Cambodia. *Food Nutr. Bull.* **34**: 169–184.

30. Olney, D., L. Bliznashka, A. Pedehombga, et al. 2015. Women’s nutrition and empowerment are improved through participation in an integrated agriculture and nutrition program in Burkina Faso. *FASEB J.* **29**(Suppl. 1): 898.

31. Olney, D.K., A. Pedehombga, M.T. Ruel, et al. 2015. A 2-year integrated agriculture and nutrition and health behavior change communication program targeted to women in Burkina Faso reduces anemia, wasting, and diarrhea in children 3–12.9 months of age at baseline: a cluster-randomized controlled trial. *J. Nutr.* **145**: 1317–1324.

32. Quisumbing, A.R., D. Rubin, C. Manfre, et al. 2015. Gender, assets, and market-oriented agriculture: learning from high-value crop and livestock projects in Africa and Asia. *Agric. Hum. Values* **32**: 705–725.

33. Ruel, M.T., P. Menon, J.P. Habicht, et al. 2008. Age-based preventive targeting of food assistance and behaviour change and communication for reduction of childhood undernutrition in Haiti: a cluster randomised trial. *Lancet* **371**: 588–595.

34. Ericksen, P.J. 2008. Conceptualizing food systems for global environmental change research. *Glob. Environ. Chang.* **18**: 234–245.

35. Global Panel on Agriculture and Food Systems for Nutrition. 2014. How can agriculture and food system policies improve nutrition? Technical Brief. London.

36. Herforth, A., E.A. Fromilgo, F. Sassi, et al. 2014. Toward an integrated approach to nutritional quality, environmental sustainability, and economic viability: research and measurement gaps. *Ann. N.Y. Acad. Sci.* **1332**: 1–21.

37. International Food Policy Research Institute (IFPRI). 2015. Global Nutrition Report 2015: Actions and Accountability to Advance Nutrition and Sustainable Development. Washington, D.C. International Food Policy Research Institute. Accessed February 13, 2017. https://www.ifpri.org/publication/global-nutrition-report-2015.

38. International Food Policy Research Institute (IFPRI). 2016. 2016 Global Food Policy Report. Washington, D.C.: International Food Policy Research Institute.

39. Gelli, A., C. Hawkes, J. Donovan, et al. 2015. Value chains and nutrition: a framework to support the identification, design, and evaluation of interventions. IFPRI Discussion Paper. Washington, DC: International Food Policy Research Institute (IFPRI).

40. World Bank. 2016. *Future of food—shaping the global food system to deliver improved nutrition and health*. Washington, D.C.: World Bank.

41. Joshi, P.K. & P. Parthasarathy Rao. 2016. Global and regional pulse economies—current trends and outlook. IFPRI Discussion Paper. International Food Policy Research Institute (IFPRI), Washington, DC.

42. Food and Agriculture Organization of the United Nations (FAO). 2014. Food outlook—biannual report on global food markets. Food and Agriculture Organization of
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42

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the United Nations, Rome. Accessed February 13, 2017. http://www.fao.org/3/a-i3751e.pdf.

43. Food and Agriculture Organization of the United Nations (FAO). 2016. Pulses—nutritious seeds for a sustainable future. Food and Agriculture Organization of the United Nations, Rome. Accessed February 13, 2017. http://www.fao.org/3/a-i5528e.pdf.

44. Bouis, H.E., P. Ebenou & A. Rahman. 2011. Food prices, household income, and resource allocation: socioeconomic perspectives on their effects on dietary quality and nutritional status. Food Nutr. Bull. 32(1 Suppl.): S14–S23.

45. Johnson, N., H. Guedenet & A. Saltzman. 2015. What will it take for biofortification to have impact on the ground? Theories of change for three crop–country combinations. IFPRI Discussion Paper, International Food Policy Research Institute (IFPRI), Washington, DC.

46. HarvestPlus. 2016. Assessing the adoption of high iron bean varieties and their impact on iron intakes and other livelihood outcomes in Rwanda. Listing exercise report. HarvestPlus, Washington, DC.

47. Cunningham, K. 2009. Connecting the milk grid: smallholder dairy in India. In Millions Fed. D.J. Spielman & R. Pandya-Lorch, Eds.: 117–124. Washington, DC: International Food Policy Research Institute.

48. Grow More Pulses Knowledge Exchange. 2016. Knowledge centre. Accessed August 15, 2016. http://www.tata growmorpulses.com/.

49. Kissinger, G. 2016. Pulse crops and sustainability: a framework to evaluate multiple benefits. Food and Agriculture Organization of the United Nations, Rome. Accessed February 13, 2017. http://ifpp2016.org/images/pdf/Pulse-crops_sustainability-framework_final_April-18-2016.pdf.

50. Mensah, P. & A. Tomkins. 2003. Household-level technologies to improve the availability and preparation of adequate and safe complementary foods. Food Nutr. Bull. 24: 104–125.

51. i-Shakti Dals. 2016. About i-Shakti dals. Accessed August 15, 2016. http://www.ishaktidals.com/About_I-shakti.html.

52. Chakrabarti, S., A. Kishore & D. Roy. Effectiveness of food subsidies in raising healthy food consumption: public distribution of pulses in India. IFPRI Discussion Paper. International Food Policy Research Institute (IFPRI), Washington, DC.

53. Farming First. 2016. Edouard Nizeyimana: purchasing pulses to support women producers. March 8, 2016. Accessed August 15, 2016. http://www.farmingfirst.org/2016/03/edouard-nizeyimana-purchasing-pulses-to-support-women-producers/.

54. Pingali, P. 2015. Agricultural policy and nutrition outcomes—getting beyond the preoccupation with staple grains. Food Secur. 7: 583–591.

55. Haas, J.D., S.V. Luna, M.G. Lung’a holo, et al. 2016. Consuming iron biofortified beans increases iron status in Rwandan women after 128 days in a randomized controlled feeding trial. J. Nutr. 146: 1586–1592.

56. Petry, N., E. Boy, J.P. Wirth, et al. 2015. Review: The potential of the common bean (Phaseolus vulgaris) as a vehicle for iron biofortification. Nutrients 7: 1144–1173.

57. HarvestPlus. 2014. AfroPop, Rap and R&B musicians promote healthier diets—through beans. November 7, 2014. Accessed August 12, 2016. Accessed February 13, 2017. http://www.harvestplus.org/knowledge-market/in-the-news/afropop-rap-and-rb-musicians-promote-healthier-diets%E2%80%94through-beans.

58. Bloom, D.E., E.T. Caferio, E. Jané-Llopis, et al. 2011. The global economic burden of non-communicable diseases. World Economic Forum, Geneva. Accessed February 13, 2017. http://apps.who.int/medicinedocs/documents/s18806en/s18806en.pdf.

59. Imamura, F., R. Micha, S. Khatibzadeh, et al. 2015. Dietary quality among men and women in 187 countries in 1990 and 2010: a systematic assessment. Lancet Glob. Health 3: e132–e142.

60. OECD. 2014. OECD health statistics 2014: how does India compare? Accessed February 13, 2017. http://www.oecd.org/els/health-systems/Briefing-Note-INDIA-2014.pdf.

61. Ha, V., J.L. Sievenpiper, R.J. de Souza, et al. 2014. Effect of dietary pulse intake on established therapeutic lipid targets for cardiovascular risk reduction: a systematic review and meta-analysis of randomized controlled trials. Can. Med. Assoc. J. 186: E252–E262.

62. Kim, S.J., R.J. de Souza, V.L. Choo, et al. 2016. Effects of dietary pulse consumption on body weight: a systematic review and meta-analysis of randomized controlled trials. Ann. J. Clin. Nutr. 103: 1213–1223.

63. Li, S.S., C.W. Kendall, R.J. Souza, et al. 2014. Dietary pulses, satiety and food intake: a systematic review and meta-analysis of acute feeding trials. Obesity 22: 1773–1780.

64. Jayalath, V.H., R.J. de Souza, J.L. Sievenpiper, et al. 2014. Effect of dietary pulses on blood pressure: a systematic review and meta-analysis of controlled feeding trials. Am. J. Hypertens. 27: 56.

65. Sievenpiper, J.L., C.W.C. Kendall, A. Esfahani, et al. 2009. Effect of non-oil-seed pulses on glycaemic control: a systematic review and meta-analysis of randomised controlled experimental trials in people with and without diabetes. Diabetologia 52: 1479–1495.

66. Thow, A.M., S. Kadiyala, S. Khandelwal, et al. 2016. Toward food policy for the dual burden of malnutrition and obesity: an exploratory policy space analysis in India. Food Nutr. Bull. pii: 0379572116653863.

67. Dubé, L., S. Jha, A. Faber, et al. 2014. Convergent innovation for sustainable economic growth and affordable universal health care: innovating the way we innovate. Ann. N.Y. Acad. Sci. 1331: 119–141.

68. Jha, S.K., J. McDermott, G. Bacon, et al. 2014. Convergent innovation for affordable nutrition, health, and health care: the global pulse roadmap. Ann. N.Y. Acad. Sci. 1331: 142–156.