3. Agricultural production for better nutrition[15]

Many opportunities exist to increase the contribution of agricultural production to improving nutrition. This chapter reviews strategies for enhancing the nutritional performance of agricultural production in three main areas: making food more available and accessible; making food more diverse and production more sustainable; and making food itself more nutritious.

Making food more available and accessible

The most fundamental way in which agricultural production contributes to nutrition is by making food more available and affordable through agricultural productivity growth. This strategy is particularly appropriate in settings where undernutrition and micronutrient deficiencies are the primary malnutrition concern. The foundation of the strategy rests on enhancing the productivity of the agriculture sector and providing an enabling environment for agricultural investment and growth (FAO, 2012c). The economic pathways through which productivity growth in agriculture makes food more available and affordable are through income growth, broader economic growth and poverty reduction, and lower real food prices.

Agricultural productivity growth and malnutrition

One of the key drivers of agricultural productivity growth is agricultural R&D. The introduction of higher-yielding varieties of rice, wheat and maize during the Green Revolution led to major improvements in nutrition through higher incomes and lower prices for staple foods (Alston, Norton and Pardey, 1995). It has been estimated that world food and feed prices would be 35–65 percent higher, average caloric availability 11–13 percent lower and the percentage of children malnourished in developing countries 6–8 percent higher had the Green Revolution not occurred (Evenson and Rosegrant, 2003).

Agricultural R&D for staple food productivity growth continues to be one of the most effective means of reducing hunger and food insecurity. Estimates from Madagascar show that a doubling of rice yields would reduce the share of households that are food-insecure by 38 percent, shorten the average hungry period by one-third, increase real unskilled wages in the lean season by 89 percent (due to both price and labour demand effects) and benefit all of the poor, including unskilled workers, consumers and net-selling rice farmers. Moreover, it would provide the biggest gains to the poorest through lower food prices and higher real wages for unskilled workers (Minten and Barrett, 2008).

Productivity growth allows farmers to produce more food with the same amount of resources, making the sector more economically efficient and environmentally sustainable. Farmers benefit directly: they earn higher incomes and can use the extra production to enhance their own household food consumption. In a second round of benefits, productivity growth enables farmers to hire additional workers and buy other goods and services, creating "multiplier effects" that can ripple throughout the economy, stimulating overall economic growth and reducing poverty (Hayami *et al.*, 1978; David and Otsuka, 1994).

Agricultural growth has been found to be much more effective than general economic growth at reducing poverty for the very poor. Growth in agriculture reduces 1 dollar-a-day headcount poverty more than three times faster than growth in non-agricultural sectors (Christiaensen, Demery and Kuhl, 2011). The

[15] This chapter is based in part on Miller and Welch (2012).

income and poverty effects of agricultural productivity growth are, of course, strongest in countries where agriculture is a large part of the economy and employs a large share of the labour force.

Several recent studies have established that sustained income growth, whether from agriculture or other sources, can have a sizeable effect on reducing malnutrition. For example, relatively strong, sustained per capita income growth of 2.5 percent per year for 20 years (a total of approximately 65 percent increase in income), would reduce the prevalence of underweight among children in developing countries by only 27 percent (Haddad *et al.*, 2003). Using regression analysis to adjust for several factors, Headey (2011) found that agricultural growth had a large effect in reducing stunting and underweight among children in the majority of the 89 surveys included in his sample. The amount of reduction resulting from growth in agriculture production and productivity depends greatly on a country's economic structure and the characteristics of malnutrition (Ecker, Breisinger and Pauw, 2011; Headey, 2011).

However, the relationship between agricultural and economic growth and improved nutrition is not automatic. India has experienced rapid agricultural and economic growth accompanied by improvements in most indicators of undernutrition among children, but the rate of progress has been far slower than that seen in other parts of the world and the prevalence of undernutrition remains among the highest in the world (Deaton and Drèze, 2009).

A closer look at available data describing periods of success or failure in reducing child malnutrition reveals a more nuanced picture. Agricultural productivity growth was associated with reductions in the prevalence of child malnutrition in most countries, including India, during the period of rapid adoption of Green Revolution technologies and up until the early 1990s. Since 1992, however, agricultural growth has not been associated with improved nutrition among children in many Indian states (Headey, 2011).

Various explanations have been offered for the persistence of high levels of undernutrition in India. These include economic inequality, gender inequality, poor hygiene, lack of access to clean water and other factors beyond the performance of the agriculture sector. However, the phenomenon remains largely unexplained and additional research is needed (Deaton and Drèze, 2009; Headey, 2011). The available evidence shows that agricultural and economic growth is effective in sustainably reducing malnutrition in low-income countries where many people depend on agriculture, but the impact is slow and may not be sufficient. Therefore, additional complementary ways to reduce malnutrition are necessary.

In addition to raising incomes and reducing poverty, agricultural productivity growth benefits consumers, both rural and urban. Through reducing the real price of food, it makes food more available and accessible, providing people with the opportunity to consume better diets. Lower real food prices enable consumers to fulfil their staple food requirements with a smaller share of their household budget, which means they can diversify their diets with other nutrient-dense foods such as meat, milk, fruits and vegetables.

Figure 6 (see page 22) shows the relationship between agricultural GDP-per-worker and the burden of malnutrition. It suggests that relatively high levels of agricultural productivity are needed before people diversify their diets sufficiently to satisfy their micronutrient needs. For young children, other mediating factors may inhibit the impact of income growth on nutrition, such as parental education, women's social status and access to health care and clean water.

Agricultural policy for better nutrition

Appropriate agricultural policies can influence agricultural productivity and nutritional outcomes, but such policies rarely have enhanced nutrition as a primary policy objective. Agricultural policies in many countries are quite complex and may influence nutrition in contradictory ways. Their impacts on nutrition may also vary according to the economic and nutritional context of the country. Agricultural policies that provide appropriate incentives and clear market signals that promote the sustainable intensification and diversification of production will improve nutrition more effectively.

Making food more available and accessible benefits people who are at risk of food insecurity and undernutrition; however, some have blamed agricultural policies in Organisation for Economic Co-operation and Development (OECD) countries for increasing overweight and obesity by making processed foods more widely available and cheaper than foods such as fruits and vegetables (Schäfer Elinder, 2005; Schoonover and Muller, 2006; Mozaffarian *et al.*, 2012). On the other hand, the Common Agricultural Policy in European countries actually raises consumer prices of sugar and dairy products relative to prices of fruits and vegetables and thus may have a small positive impact on the overall healthiness of European diets (Capacci *et al.*, 2012). Similarly, Alston, Sumner and Vosti (2006) found that agricultural subsidies in the United States of America have relatively small and mixed impacts on the prices of farm commodities, raising sugar prices and lowering maize prices, for example. They concluded that eliminating farm subsidies in the United States of America would have negligible consequences for overweight and obesity rates. Schmidhuber (2007) cautioned that whereas the Common Agricultural Policy served largely as a tax on consumers in the European Union (EU), it may have depressed prices and encouraged overconsumption in countries that imported food from the EU.

Hawkes *et al.* (2012) considered the impact of agricultural policies on diets throughout the world. They hypothesized that market liberalization since the 1980s has made food more readily available and affordable in many countries, but because both more nutritious and less nutritious foods have been affected, they concluded that this has had both positive and negative implications for the overall healthiness of diets. With rising incomes and increased affordability of a range of foods, factors such as convenience and responsiveness to nutrition education may be key variables in determining the effects of agricultural policies on nutrition.

In addition to the commodity support policies common in OECD countries, many developing countries subsidize agricultural inputs, mainly fertilizer and seeds, with a view to boosting smallholder crop production and achieving national food self-sufficiency. Levels of agricultural support in OECD and developing countries have converged since the 1980s, with the former falling significantly while the latter have risen (FAO, 2012c). Evidence from farm input subsidy programmes in India and Malawi indicates that they can significantly boost agricultural production and farmers' incomes, albeit at a high budgetary cost (HLPE, 2012), but the impact of such policies on nutrition has not been well studied. Input subsidies can be beneficial if targeted to specific groups, such as women, who are relatively more constrained in their access to commercial inputs (FAO, 2011b). As noted below, fertilizer subsidies may also have some nutritional public good attributes, with benefits to a wider population beyond the immediate beneficiaries. In general, the costs of input subsidies and their indirect effect on nutrition probably mean that other, more targeted, nutrition interventions would be more effective.

Gender and seasonal considerations

Efforts to boost agricultural productivity must also consider the impacts on time use – especially of women, who bear a greater responsibility for food preparation and child care (FAO, 2011b). Maternal and child nutrition are particularly vulnerable to the seasonal time demands placed on female agricultural workers. Disruptions to adequate maternal nutrition and good care and feeding practices during the critical "1 000 days" from conception through the first two years of life can cause lasting damage to women's health and life-long physical and cognitive impairment in children (Box 5). Understanding the nutritional consequences of the time constraints on rural women, investing in infrastructure and technology to alleviate these burdens and making specific nutrition-related interventions during critical periods in the agricultural calendar can help improve nutritional outcomes for women and children.

Agricultural interventions need to take into account the effect of seasonality on nutritional outcomes. Vaitla, Devereux and Swan (2009) note that much of the undernutrition in the world is due to the annual "hunger season". Particularly in areas dependent on rain-fed cultivation, the year-to-year availability of food is the key determinant of fluctuations in undernutrition

BOX 5
The first thousand days

Maternal and child undernutrition is the primary pathway through which poverty is transmitted from one generation to the next. About a quarter of all children under the age of five are stunted and about half suffer from one or more deficiencies in a key micronutrient. The critical window for adequate child growth and cognitive development is between conception and 24 months of age. Developmental damage that results from undernutrition during this period cannot be reversed or regained over time. For this reason, many national and international nutrition initiatives now focus on the first 1 000 days.

A recent series of articles in *The Lancet* in 2008 recommended a number of strategies for addressing undernutrition in mothers and young children, from which Horton *et al*. (2010) identified 13 highly cost-effective interventions. These interventions emphasized care and feeding practices, such as improved hygiene and de-worming, exclusive breastfeeding for infants during the first six months, and vitamin and mineral supplements. Food system interventions identified in this work were limited primarily to the provision of micronutrients through fortified foods.

Food fortification can certainly make an important contribution, but food systems can do even more to improve maternal and child nutrition during the crucial first 1 000 days. For example, while children should be exclusively breastfed for their first six months, after this time they need energy-dense, micronutrient-rich complementary foods, and older children gradually share what should be nutritious family diets. Food systems play an important role in providing, in a sustainable manner, diverse and nutritious food obtained from own production or from local markets. Nutrition education and counselling play a central role in promoting good prenatal and postnatal care and diets for the mother and child. This especially concerns the most appropriate types of complementary foods, as well as preparation, storage and feeding practices that help preserve or even increase the nutritional quality of the food (Hotz and Gibson, 2005).

Within the food system, gender roles are directly relevant for child and maternal malnutrition. Increasing women's control over resources and incomes has been shown to benefit their children's health, nutrition and education, as well as their own health and nutritional status (FAO, 2011b; World Bank, 2011). Agricultural production and food processing are the main sources of employment for women in most developing regions, yet women typically control fewer resources and earn lower incomes than men, so closing the gender gap in agriculture could produce significant nutritional gains for society, including during the first 1 000 days (FAO, 2011b).

Women in most countries also undertake most of the work related to child care, food preparation and other household responsibilities such as collecting fuel and water. Women thus face multiple trade-offs in the allocation of their time that directly impinge on their own and their children's health and nutritional status. As these trade-offs can be exacerbated by the seasonal nature of agricultural activities, attention should be paid to the effects that working conditions may have on a family's ability to care for its children. Policies, interventions and investment in labour-saving farming technologies and rural infrastructure, targeted safety nets, and services such as on-site child care can contribute significantly to health and nutritional outcomes for women, infants and young children.

and short-term deprivation (Kumar, 1987). In Malawi and the Niger, Cornia, Deotti and Sassi (2012) found that strong seasonal food price variations are a major determinant of child malnutrition; these fluctuations occur even in periods of relatively abundant harvests because of limited investment in storage at the community and household levels, limited credit availability and inadequate strategic food reserves.

Dietary energy requirements for agricultural households are higher during the harvest period, and food consumption increases if household food stores are adequate. In the Gambia, Kennedy and Bouis (1993) found that pregnant women were not able to compensate for higher energy expenditure during the season of peak agricultural labour demand. As a consequence, birth weights were below the international average for deliveries occurring after this period. During non-peak seasons, birth weights were close to international norms. The rainy season also coincides with increased incidence of disease, which further raises nutritional requirements. Heavy farm work coinciding with disease and reduced food availability are partly responsible for the difference in prevalence of malnutrition among rural and urban adults.

Making food more diverse

Sustained agricultural productivity growth, income growth and poverty reduction – whether from agriculture or other sources – can improve nutritional outcomes, but the mixed impacts of agricultural policies and the slow impacts of agricultural R&D on productivity growth suggest that there is room for improvement. Specific interventions aimed at diversifying what farmers produce and what food households have access to (e.g. through home gardens or raising small animals) can contribute to better nutrition.

Diversification at national scale

Agricultural policies, including R&D, can be used to make the food supply more diverse, although few countries have made diversification a specific policy objective. Some European governments have attempted to use agricultural policies to improve diets by reducing support for foods considered to be less healthy and investing more in other foods such as fruits and vegetables. In Finland, for example, the government implemented agricultural policy reform along with media and education campaigns to encourage the production and consumption of healthier foods. The reform included reducing subsidies for dairy products in favour of lean meats and promoting the production and consumption of berries (Mozaffarian *et al.*, 2012).

Agricultural R&D could be made more nutrition-sensitive by being more inclusive of small producers and focusing more resources on important non-staple foods and integrated production systems. Relatively little public agricultural R&D focuses on increasing the productivity of nutrient-dense foods such as fruits, vegetables, legumes and animal-source foods. Improved productivity would reduce the relative prices of these foods and could support dietary diversity. Post-harvest research could extend the limited seasonal availability and reduce the nutrient losses and food safety hazards associated with these highly perishable foods (see Chapter 4).

Diversifying home and small farm food production

Increasing micronutrient availability for poor households with limited access to land, in both urban and rural areas, is a particular challenge. Projects that support the diversification of home and smallholder production hold potential for improving consumption of a variety of foods and reducing micronutrient deficiencies. For example, in Kenya and the United Republic of Tanzania, a project aimed at promoting the production, marketing and consumption of traditional African vegetables among smallholders found that increasing crop diversity was associated with increased dietary diversity (Herforth, 2010).

The specific nature of these interventions depends on the type of agriculture practised and the type of constraints that households face in a given location. Such projects can range from small-scale home garden projects to more complex integrated farming projects (see Boxes 6 and 7).

Small-scale home gardens are promising interventions when micronutrient deficiencies are significant and fruit and vegetable consumption is low. Home gardening is already widely practised, can be effective on a small scale and is feasible in most locations, although water and labour constraints may pose challenges and should be carefully considered in project design.

A recent review found that most evaluations of home garden programmes were not designed to enable the assessment of impacts on nutritional status. Such studies did demonstrate increased consumption of fruits and vegetables, but the overall effect on nutrient consumption could not be assessed because they typically ignored substitution effects (Masset *et al.*, 2011).

Experience has also shown that home garden projects are more likely to be effective when accompanied by nutrition information and education and by a focus on roles traditionally held by women (such as child care and food preparation) as well as women's empowerment (World Bank, 2007a). Programmes in West Africa (Box 6) and Ethiopia (Box 7) illustrate the benefits that can accrue to such integrated action.

In some communities, micronutrient intakes can be enhanced more effectively by strengthening animal husbandry. For example, in Ethiopia, the important role of goats in the mixed farming systems of the high- and mid-altitude areas led to development of the FARM-Africa Dairy Goat Development Project (Ayele and Peacock, 2003). The project focused on increasing income and milk consumption by raising the productivity of local goats managed by women through a combination of improved management techniques and genetic improvements. The intervention led to an increase in the per capita availability of milk by 119 percent, energy from animal sources by 39 percent, protein by 39 percent and fat by 63 percent. Through impact analysis of data on those households within the project area, FARM-Africa demonstrated a considerable improvement in the nutritional status and family welfare of project participants (Ayele and Peacock, 2003).

Few of the home production interventions that target nutrition have been successfully scaled up. One exception is the Homestead Food Production (HFP) project, introduced in Bangladesh by Helen Keller International nearly two decades ago. This project initially focused on reducing vitamin A deficiency by promoting home gardens, but its scope has been widened to address iron and zinc deficiencies also by incorporating small-animal husbandry and nutrition education (Iannotti, Cunningham and Ruel, 2009). Implemented by non-governmental organization (NGO) partners and the Government of Bangladesh, HFP has expanded its reach into over one-half of the country's subdistricts and has been extended to other countries in Asia and sub-Saharan Africa.

BOX 6

Increasing dietary diversity through home gardens

Action Contre La Faim (ACF) developed an approach in West Africa based on home vegetable gardens aimed at promoting good nutrition at the household level by diversifying supply and increasing dietary diversity. This approach, called "Health & Nutrition Gardens" also aims at empowering women to sustain good nutrition in their families. Apart from facilitating access to inputs, training on crop production, and post-harvest conservation, ACF's approach also includes:

- evaluation of food consumption patterns;
- selection of micronutrient-rich vegetables to enrich deficient diets;
- research into recipes that seek to provide a balanced diet based on local foods;
- cooking demonstrations;
- awareness-raising and nutrition education to improve maternal and child-feeding practices.

The results have been positive. The supply of vegetables has increased by over 160 percent and vegetables are now available for nine months of the year, compared with five months before the programme. Dietary diversity at the household level has improved and consumption, especially of foods rich in vitamin A, has improved markedly. Participants' knowledge of the causes of malnutrition has also increased to 88 percent compared with 68 percent among non-participants.

The positive experience with these "Health & Nutrition Gardens" has led ACF to scale up the programme in West Africa, as well as in Asia, the Caucasus and Central and South America.

Source: Contributed by ACF International.

BOX 7
Improving child nutrition in small-scale pastoral food systems

Child malnutrition is severe among pastoral communities in the Somali region of Ethiopia, (Mason *et al*., 2010). A substantial proportion of the population's dietary intake and income is derived from livestock products. Save the Children's Milk Matters project aimed to improve the ways that animal husbandry and livestock production can benefit the nutritional status of local children.

In the first phase of the project, a participatory approach was used to identify which factors pastoralists considered the most important in affecting the nutrition of their children. Participants identified the availability of milk as a key factor. They noted that the health and nutrition of livestock, as well as the seasonal migration of livestock, which took them away from young children, were major factors affecting this availability.

The project therefore aimed to improve the food security and nutritional status of children by addressing these factors and improving the milk production system. It maintained the health of livestock by providing supplementary feed, vaccinations and de-worming as well as ensuring the availability of a sufficient water supply.

Results from the Milk Matters evaluation (Sadler *et al*., 2012), carried out by Save the Children in collaboration with Tufts University, found that milk availability and consumption by young children improved in the intervention sites relative to the control sites. By the end of the intervention, 90 percent of the children in Waruf were given milk, compared with only 31 percent in the control region, Fadhato.

Where the intervention worked well and intervention coverage of households was high, the increase in milk consumption seen (1 050 ml/day compared with 650 ml/day in the control site) translated into an additional 264 kcal of energy, 12.8 g of protein and considerably higher intakes of essential fatty acids, vitamins and minerals per child each day. For a two-year-old child this increase in nutrient intake would meet around 26 percent of energy and 98 percent of protein requirements.

Nutritional impacts were seen in the intervention sites. During a severe drought, the nutritional status of children in the intervention sites remained stable while it deteriorated significantly in non-intervention sites during the period of the programme.

This intervention improved nutritional outcomes for children, while at the same time enabling families to retain key assets (in the form of livestock) during a period in which significant risks to food and nutrition security unfolded. The project shows that food production systems, including pastoralist husbandry, can be shaped so that they enhance household livelihoods and simultaneously lead to improvements in child nutrition.

Source: Contributed by Save the Children (UK).

Evidence shows that HFP programmes in Bangladesh have improved food security for almost 5 million vulnerable people in diverse agro-ecological zones. There is convincing evidence of HFP's impact on household production, improved dietary quality and intake of micronutrient-rich foods, but neither improvements in actual micronutrient status nor the cost-effectiveness of the approach have been fully demonstrated (Iannotti, Cunningham and Ruel, 2009).

A recent review of household food production strategies and their effect on nutrition by Girard *et al.* (2012) notes that many factors determine the effectiveness of such strategies in influencing nutritional outcomes. For one, when infectious disease is common, additional interventions are needed as the impacts of production strategies will be limited. The review also found that the impacts of production strategies are difficult to discern because it is hard to establish how much of the additional output is sold and how much of the food consumed at home is consumed by women and children. The authors concluded that the existing evidence, although scarce, indicates that production strategies can improve intakes of micronutrient-rich foods by women and young children when they have clear nutrition objectives and integrate nutrition education and gender considerations.

In Viet Nam, the VAC (Vuon, Ao, Chuong – Crop farming, Aquaculture, Animal husbandry) system is one such integrated approach that seems to have produced positive effects on nutrition. The VAC system typically includes: a pond stocked with fish placed close to the home; livestock or poultry pens situated near or over the pond to provide an immediate source of organic fertilization; and gardens that include both annual and perennial crops for year-round food provision and products for market. Viet Nam's National Nutrition Survey 2000 showed marked improvements from 1987 in terms of animal-source foods and fruit and vegetable consumption. Although this progress is due to multiple factors, VAC is considered to have played an important role (Hop, 2003). As a result, the prevalence of child malnutrition and chronic energy deficiency in women of reproductive age decreased and there was a substantial increase in the incomes and the health and nutrition of Vietnamese rural populations (Hop, 2003).

As suggested above, production projects are more likely to succeed when gender roles are taken into account in project design and implementation (Berti, Krasevec and Fitzgerald, 2004; Quisumbing and Pandolfelli, 2010). Implementation modalities are important (Kumar and Quisumbing, 2011). Gender-specific time constraints are particularly important. Strategies that place new time demands on women can reduce the time available for breastfeeding, child care, food preparation and fetching water – all of which are related to nutrition. New time demands can also reduce the time available to cultivate nutrient-dense foods in kitchen gardens or acquire such food from the market. Policies and projects that make productivity-enhancing, time-saving technologies and approaches for activities traditionally undertaken by women, such as fetching water and firewood, weeding, hoeing, food processing and local marketing of produce, can significantly enhance the nutrition of women and children (Herforth, Jones and Pinstrup-Andersen, 2012; Kes and Swaminathan, 2006; Gill *et al.*, 2010).

Making food more nutritious

Poor households' diets typically rely on a single starchy staple to provide the bulk of energy consumed. Non-staple foods that are high in micronutrients – such as milk, eggs, fish, meat, fruits and vegetables – are often too expensive for the poor to purchase in adequate quantities. Dietary diversity is often a luxury that the poor cannot afford. Several approaches seek to enhance the diversity of the foods that the poor themselves produce.

Agronomic practices to improve nutrition

Improving the fertility of soils through the use of organic or inorganic fertilizers containing balanced concentrations of nitrogen, potassium and phosphorous can enhance crop yields and improve the micronutrient concentrations in crops. Adding specific micronutrients to fertilizers or irrigation water can further enhance yields and micronutrient concentrations.

Adding micronutrients to soils in the Indian states of Andhra Pradesh, Madhya Pradesh and Rajasthan enhanced yields by 20–80 percent and a further 70–120 percent when micronutrients were added in conjunction with nitrogen and phosphorous (Dar, 2004). These results were found for a number of crops, including maize, sorghum, greengram, pigeonpea, castor, chickpea, soybean and wheat. Yield increases achieved through balanced crop fertilization can reduce the land area needed to grow staple crops and thus add to the sustainability of the farming system.

Additions of iodine, in the form of potassium iodate, to irrigation water have been used to eliminate iodine deficiency in villages in northwestern China (Cao *et al.*, 1994; Ren *et al.*, 2008). A single application of iodine to the farmers' fields corrected iodine deficiencies in villagers consuming the crops grown on these fields for at least four years at a low cost of around US$0.05 per person per year. Livestock productivity also improved by around 30 percent because livestock in the region had previously been iodine-deficient.

Dietary zinc deficiencies can also be addressed through the use of micronutrient fertilizers in rice production, although complementary interventions such as plant selection, breeding local varieties for zinc content and changing cooking methods are also beneficial (Mayer *et al.*, 2011). The authors conclude that these changes, taken together, could potentially double the zinc content of rice and increase children's total dietary zinc intake by more 50 percent.

While micronutrient-enriched fertilizer is a promising technology, both in terms of nutritional efficacy and economic efficiency, several challenges have so far limited its adoption by farmers. Assessing micronutrient availability in soils is complex, and there is a lack of quantitative data on the micronutrient density of food crops grown on different types of soil (Nubé and Voortman, 2011).

Farmers must perceive an incentive to use micronutrient fertilizers either in the form of nutritional benefits or economic benefits such as higher yields or a market premium for the product. Because most micronutrients are not readily visible to consumers, farmers would be unlikely to receive a premium in the absence of effective education, marketing and labelling campaigns. Governments that already provide incentives for fertilizer use might consider including micronutrient fertilizers as their nutritional effects offer clear public good benefits that represent an investment in human capital.

Biofortification through plant breeding

Biofortification is a nutrition-specific intervention designed to enhance the micronutrient content of foods through the use of agronomic practices and plant breeding. Unlike food fortification, which occurs during food processing (discussed in Chapter 4), biofortification involves enriching the micronutrient content of plants. Biofortification can benefit farm households that produce primarily for their own consumption, as well as urban and rural households that purchase biofortified foods (Bouis *et al.*, 2011).

Plant breeders typically consider a range of objectives in developing a new crop variety, such as yield, disease resistance, processing characteristics and cooking qualities. In the process of biofortification, breeders give relatively higher priority to nutritional content among these objectives.

Biofortification through plant breeding can involve conventional varietal selection and breeding or more advanced molecular biology techniques such as marker-assisted selection or genetic engineering. Breeders can use the existing genetic diversity in a crop species and its wild relatives to identify, select and breed varieties that have higher nutritional content. Where a nutritional trait does not exist within the genome of the target crop, genetic engineering can be used to introduce the trait from another species. Biofortification programmes typically focus on staple grains or tubers and are aimed at smallholder farmers, although biofortified crops can also be cultivated by large-scale commercial farmers.

Biofortified crops can entail high start-up costs in the form of research, development and dissemination, but once biofortified staples are integrated into the food chain, they continue to provide micronutrient intervention with little additional input (Qaim, Stein and Meenakshi, 2007). In 2008, biofortification interventions were ranked the fifth most cost-effective development intervention by the Copenhagen Consensus (2008).

The Consultative Group on International Agricultural Research (CGIAR) programme HarvestPlus carries out extensive R&D on biofortification, relying on conventional plant breeding.[16] Starting in 2003, HarvestPlus has been developing and delivering biofortified staples in countries with populations most at risk of micronutrient deficiencies. Table 2 lists the expected release years for various biofortified crops being developed by the HarvestPlus programme. Widespread adoption is expected to take another decade.

The most promising results so far have been achieved with orange-fleshed sweet potato (OFSP). Unlike the typical white and yellow sweet potato varieties produced in Southern Africa, orange varieties are rich in vitamin A. HarvestPlus selected and adapted

[16] See HarvestPlus (2011) for more details.

TABLE 2
Biofortified staple food crops implemented by the HarvestPlus programme and actual or expected release year

BIOFORTIFIED CROP	MICRONUTRIENT	COUNTRY OF FIRST RELEASE	AGRONOMIC TRAIT	YEAR
Sweet potato	Provitamin A	Mozambique, Uganda	Disease resistance, drought tolerance, acid soil tolerance	2007
Cassava	Provitamin A	Democratic Republic of the Congo, Nigeria	Disease resistance	2011
Bean	Iron, zinc	Democratic Republic of the Congo, Rwanda	Virus resistance, heat and drought tolerance	2012
Maize	Provitamin A	Zambia	Disease resistance, drought tolerance	2012
Pearl millet	Iron, zinc	India	Mildew resistance, drought tolerance, disease resistance	2012
Rice	Iron, zinc	Bangladesh, India	Disease and pest resistance, cold and submergence tolerance	2013
Wheat	Iron, zinc	India, Pakistan	Disease and lodging resistance	2013

Note: HarvestPlus also supports biofortification of banana/plantain (vitamin A), lentil (iron, zinc), potato (iron, zinc) and sorghum (iron, zinc).
Source: Modified from Bouis *et al.*, 2011.

orange-fleshed varieties grown in Northern America to suit the agronomic conditions found in Southern Africa and introduced them to more than 24 000 households in Mozambique and Uganda. Beyond plant breeding, the programme worked closely with farmers and consumers to ensure compatibility with consumer preferences and to promote behaviour change and dissemination. Many existing sweet potato farmers switched to the orange variety from yellow or white varieties, and many others were new to cultivating sweet potatoes.

The OFSP intervention in both countries significantly increased vitamin A intake among children and women in the relevant households (Hotz, *et al.*, 2012). In Uganda, this was associated with a lower likelihood of vitamin A deficiency among children and women. At follow-up, the OFSP was found to be the dominant source of vitamin A in the diet, providing 80 percent of total vitamin A intake among reference children (Hotz *et al.*, 2011).

Questions remain about the readiness of consumers to purchase biofortified foods, especially when they look or taste different from traditional varieties. Receptivity is likely to vary depending on the crop and trait, local tastes and preferences, and the breeding technique. Early evidence regarding OFSP suggests that consumers are willing to buy them and may even pay a premium. In Uganda, consumers are willing to pay as much for the orange-fleshed varieties of sweet potato as for the white varieties even in the absence of a promotional campaign, and they are willing to pay a significant premium when provided with information about their nutritional benefits (Chowdury *et al.*, 2011). Similar results were found for nutritionally enhanced orange maize in Zambia, where consumers did not confuse it with ordinary yellow or white maize and were willing to pay a premium when its introduction was accompanied by nutrition information (Meenakshi *et al.*, 2012).

Success in introducing and establishing biofortified crops will be helped by understanding gender roles in production, consumption and marketing of these foods (Bouis and Islam, 2012a). Women's role as caregivers and in food preparation may make them particularly receptive to foods that have specific health attributes. In Uganda, OFSP uptake has been encouraged for health and nutrition reasons, which may have contributed to making women more likely to grow these varieties on the parcels they control (Gilligan *et al.*, 2012). Bouis and Islam (2012a, p. 2) report that "a key factor in the success of OFSP was the critical role played by women, both as caregivers of young children and as producers and retailers of OFSP".

Genetic engineering is being used to enhance the vitamin and mineral content and bioavailability of some staple crops where these traits are not available within the target crop genome (Waters and Sankaran, 2011; White and Broadley, 2009). Research is under way on nutrients such as vitamins A and E, riboflavin, folic acid, iron and zinc. The best-known example is "Golden Rice", which was developed by the Golden Rice Network, an international consortium of public research institutions, and is currently undergoing pre-market testing.

The potential of biofortified crops is high but, with the exception of OFSP, their nutritional efficacy and sustainability have not yet been well established. In response to this, HarvestPlus partners are studying these issues with regard to biofortified beans, pearl millet, wheat, rice, cassava and maize. The first round of findings should be available in 2013 (Bouis and Islam, 2012b).

Conclusions and key messages

Agricultural production and productivity growth support nutritional outcomes through their traditional roles of generating incomes for populations that depend on the sector for their livelihoods and by making food more available and accessible for all consumers. Agricultural productivity growth makes food more sustainable by reducing the resources required for production. If research priorities focus more closely on integrated production systems and nutrient-dense fruits, vegetables, legumes and livestock products, then agricultural production can contribute more to making food more diverse and nutritious.

Agricultural productivity growth depends on the existence of an enabling policy and institutional environment – good governance, macroeconomic stability, rural infrastructure, secure property rights (especially for women) and effective market institutions (FAO, 2012b). Agricultural R&D is necessary to maintain productivity growth but also to improve the diversity, sustainability and nutritional quality of the food supply.

Agricultural support policies could be more conducive to better nutrition by rebalancing support to favour healthier, more sustainable diets. Current policies have fewer nutritional impacts than they could if they included nutrition among their primary objectives.

Key messages

- Agricultural production contributes to better nutrition by making food more available and accessible. The traditional roles of agricultural production and productivity growth in generating incomes and reducing food prices will continue to be of crucial importance in the coming decades. At the same time, the sector can and must do more to improve the sustainability, diversity and nutritional quality of food.
- Agricultural production policies should focus on creating an enabling environment and allowing market signals to encourage production. Agricultural R&D priorities must continue to include the sustainable intensification of staple food production, but must also be made more nutrition-sensitive, with a stronger focus on nutrient-dense foods such as legumes, fruits, vegetables and animal-source foods. Greater efforts must be directed towards interventions that diversify smallholder production, such as integrated farming systems. Efforts to raise the micronutrient content of staples directly through biofortification are particularly promising. Agricultural interventions are more likely to be successful in improving nutrition when they are combined with nutrition education and implemented with sensitivity to gender roles.
- A substantial body of evidence supports the crucial role of agriculture in improving nutrition, but the causal relationships are complex. Agricultural interventions generally have multiple objectives such as productivity growth, cropping diversity or income generation, and their impacts on nutrition are often indirect and dynamic. As a result, their impacts are more difficult to evaluate accurately than simple medical interventions. Ultimately, however, agricultural interventions will be much more effective as they lead to a virtuous cycle of growth, poverty reduction, improved nutrition and better health.