

From Agriculture to Nutrition

Pathways, Synergies and Outcomes



From Agriculture to Nutrition: Pathways, Synergies and Outcomes



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Acronyms and Abbreviations

AVRDC	Asian Vegetable Research and Development Center
BMI	body mass index
CDD	community-driven development
FAO	Food and Agriculture Organization (United Nations)
FRT	Farmer Research Team
HACCP	Hazard analysis critical control point
HIV/AIDS	Human Immunodeficiency Virus/Acquired Immune Deficiency Syndrome
HKI	Helen Keller International
IDRC	International Development Research Center
IFPRI	International Food Policy Research Institute
NGO	nongovernmental organization
OECD	Organization for Economic Co-operation and Development
OFSP	orange-fleshed sweet potato
SETSAN	Technical Secretariat for Food Security and Nutrition (Mozambique)
SFHC	Soils, Food and Health Communities Study (Malawi)
SWAp	sectorwide approach
TANA	The Agriculture-Nutrition Advantage Project
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
VITAA	Vitamin A for Africa
VITAL	Vitamin A Field Support Project
WFSP	white-fleshed sweet potato
WHO	World Health Organization
WTO	World Trade Organization

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Executive Summary

INTRODUCTION

In a world of food abundance, millions of people suffer from poor nutrition. In some parts of the world, the poor have inadequate access to energy from food to meet their energy requirements. In these locations, food shortage is often a seasonal phenomenon and micronutrients are also generally lacking in the diet. Elsewhere, there is a stable supply of energy but the poor have monotonous diets lacking in essential micronutrients. In other places a “nutrition transition” is under way in which the poor and other consumers enjoy sufficient access to energy, and indeed often consume excessive amounts, but the quality of their diets is unhealthy owing to a combination of factors relating to nutrition and lifestyle. Excessive consumption combined with more sedentary lifestyles, often associated with urbanization, contributes to an increasing incidence of obesity and chronic disease such as diabetes in countries still plagued by undernutrition. A combination of these nutritional problems adversely affects about 2 billion people worldwide.

The relationship between agriculture and human nutrition is far more complex than the relationship between food production and food consumption or the economic relationship between food supply and food demand. Increased food production raises the availability of food, but by itself does little to ensure that poor and vulnerable people have access to the food that is produced. Nor does the gross quantity produced say much about the quality or nutritional value of people’s diets. The persistence of malnutrition as a global public health concern despite the successes in increasing agricultural production belies any notion that malnutrition and undernutrition can be solved entirely from the supply side. How then can agriculture, with its customary focus on productivity and yields, more effectively contribute to improved nutrition outcomes?

Expanding agriculture’s purview and capacity to embrace those contributing factors and determinants of nutrition that are traditionally the province of other disciplines or improving agriculture’s interface with other, nonagricultural sectors, suggest themselves as possible ways forward. Those sectors that approach nutrition in relation to its essential role in building and maintaining human capital are particularly important prospective counterparts in this regard. Yet operationally integrating the necessary inputs of other sectors into agriculture interventions, or effectively coordinating the respective

contributions of sector ministries in larger development programs and policies, is in practice fraught with difficulty. Historically, multisector efforts intended to simultaneously address agriculture and nutrition have often been hindered by institutional barriers and insufficient resources.

The limitations of production-focused agricultural programs and interventions in delivering improved nutrition impacts have been recognized by some in the agricultural community for decades. In the early 1980s a number of international development agencies undertook programs that sought to orient agricultural production to nutrition-related objectives, and over time a substantial body of literature developed around the analysis of the programs' results. A review of this literature yields a number of insights as to how agricultural investments can be designed and targeted to improve nutrition outcomes. Malnutrition remains an urgent global public health concern. Yet the question of how agriculture can most effectively contribute to improved nutrition outcomes remains essentially unanswered. It is therefore time to revisit what is known and what can be done to improve the synergies between agriculture and nutrition. The potential contribution of agriculture needs to be reexamined, especially in light of the changes the sector has undergone, by reviewing lessons from past experience and by analyzing current developments and what they mean for future change. That is the purpose of this report.

OBJECTIVE

The report seeks to analyze what has been learned about how agricultural interventions influence nutrition outcomes in low- and middle-income countries, focusing on the target populations of the Millennium Development Goals—people living on less than a dollar a day. It also sets out to synthesize lessons from past efforts to improve the synergies between agriculture and nutrition outcomes. The report identifies a number of developments in agriculture and nutrition that have transformed the context in which nutrition is affected by agriculture. These developments have considerable practical significance for nutrition-related agricultural programs—including the design of those programs that aim to improve nutritional outcomes. Finally, the report draws a number of practical conclusions

that shed light on how agricultural interventions and investments may improve nutrition outcomes in low- and middle-income countries.

PATHWAYS LINKING AGRICULTURE TO NUTRITION

A widely used conceptual framework published by UNICEF in 1990 identifies three main underlying determinants of nutritional status: availability and access to food, the quality of feeding and care giving practices, and the health of the surrounding environment and access to health care services. Each of these determinants is a necessary but not sufficient condition to good nutrition. The food supply chain linking food production with food consumption and human nutrition can be usefully considered in terms of five *pathways*.

- Subsistence-oriented production for the household's own consumption
- Income-oriented production for sale in markets
- Reduction in real food prices associated with increased agricultural production
- Empowerment of women as agents instrumental to household food security and health outcomes
- Indirect relationship between increasing agricultural productivity and nutrition outcomes through the agriculture sector's contribution to national income and macroeconomic growth

Household production for the household's own consumption is the most fundamental and direct pathway by which increased production translates into greater food availability and food security. The different types of foods produced determine the impact of the production increase on diet quality. The production of staple foods leads mainly to greater access to and consumption of energy. Increased production of fruit, vegetables, and animal source foods (dairy, eggs, fish, and meat) can likewise raise access to energy, protein, and fat, but can also greatly improve the quality and micronutrient content of diets. Some proportion of the food produced may also be intended for sale on local markets. Some households may for instance meet their staples requirements themselves while depending on markets for other products such as fruits and vegetables. Others may rely mainly on home gardens for fruits and vegetables. Whatever role produc-

tion-for-income plays in this scenario is secondary to the principal purpose of producing food to meet the household's own food requirements.

Income-oriented production for sale in markets. As agricultural households become more market oriented, production-for-own-consumption becomes less significant relative to income from the sale of what is produced. Technology becomes more important relative to the household's resource endowment, and the selection of crops to be grown is based principally on their tradability and the price they are expected to command in local markets. Extra income may be used to buy more food, higher-quality (more nutrient-dense) foods, or both; the balance between the two affects the final impact of this additional income on the household's consumption of energy and micronutrients. The translation of increased income into better child nutrition, in turn, depends on a series of intrahousehold factors and processes. These include women's status, education, knowledge, health-related practices, decision-making power, income, and access to and use of health and sanitation services.

The empowerment of women is a pathway that carries special significance for household nutrition outcomes and in particular for children's health and nutrition outcomes. Women have consistently been found to be more likely than men to invest in their children's health and well-being, and the income and resources that women control wield disproportionately strong effects on health and nutrition outcomes generally. Women who are reached by agricultural programs that relay information on nutrition issues appear to be particularly effective at delivering improved nutrition outcomes, and the effects appear to be most pronounced among the lowest income groups. Taken together, these characteristics make women natural priorities for agricultural programs that aim at improving nutrition. These programs, however, must take women's time and resource constraints firmly into account and, where and when possible, seek means of relieving them.

Lowering food retail prices by increasing food production is another pathway linking agriculture to nutrition and is especially important in areas in which markets are less integrated. For net consumers, reduced food prices enable greater access to food and essential nutrients, resulting in better health and productivity for the general workforce while also freeing additional household resources

from food to other expenditures, including productive investments.

Finally, *agricultural growth* itself represents an indirect pathway to better nutrition through its contribution to macroeconomic growth and higher levels of national income, which can support nutritional improvements by reducing poverty. Increases in agricultural productivity have been vital factors in building sustained economic growth in both developed and developing countries and have major impacts on poverty. One cross-country analysis found that a 1 percent increase in agricultural yields lowers the percentage of a national population living on less than a dollar a day by between 0.64 and 0.91 percent—a poverty effect that appears particularly great in African countries (Thirtle et al. 2002). Overall, however, the economic growth-to-malnutrition relationship is modest. A doubling of gross national product (GNP) per capita in developing countries has been associated with a much more modest reduction in childhood undernutrition—on the order of 23 to 32 percent (Haddad et al. 2003).

THE IMPACT OF AGRICULTURAL INTERVENTIONS ON NUTRITION OUTCOMES

The literature reviewed in this report documents the nutrition outcomes of agricultural programs and can be usefully classified by the type of commodity the program involved: staples, fruits and vegetables, or animal source foods. Studies on the nutritional impacts of programs involving staple crops such as maize and rice focused overwhelmingly on aggregate production and food availability rather than on individual- or household-level indicators and therefore yielded little evidence that is germane to this report. Moreover, the only agricultural interventions involving staple foods that have been evaluated from a nutritional perspective concern agricultural commercialization—the conversion from staple subsistence food production to commercial food production. This type of intervention aims to improve nutritional outcomes through both the own-consumption and the income pathways, with potential indirect impacts through the agricultural growth and price pathways. Evidence from the review of studies on agricultural commercialization shows increases in household income,

including greater income controlled by women in some cases and greater household food expenditure. These changes did not, however, translate into substantial improvements in child nutrition. In order to improve childhood nutrition, agricultural commercialization interventions would most likely need to be complemented by components or parallel interventions that specifically target other determinants of child nutrition. These would include improved health, care giving practices, and access to water and sanitation facilities to address the high rates of infections affecting young children in poor environments.

Agricultural interventions promoting increased production of fruit and vegetables—such as those involving homestead gardens—carry considerable potential to effectively address micronutrient deficiencies. The review identified a significant body of evidence documenting the success of homestead gardens in raising production, income, household consumption, and the intake of targeted fruit and vegetables by vulnerable population groups. Several programs also showed significant impacts on dietary and biochemical indicators of micronutrient deficiencies, and especially so when they included components designed to change behavior through education and to empower women.

Programs and interventions involving animal source foods have even greater potential to tackle micronutrient deficiencies, especially vitamin A, iron, and zinc deficiencies. These micronutrients are more readily bioavailable in animal source foods than in plant foods. Several interventions showed gains in production, income, and household food security, and significantly greater nutrition impacts when combined with interventions involving women's empowerment, education, and behavior change.

Four case studies of agricultural interventions were reviewed because of their unique contribution to the body of knowledge on the linkages between agriculture and nutrition. They include an orange-fleshed sweet potato intervention to improve vitamin A intake in Mozambique, a legume systems and child nutrition program in Malawi, a homestead gardening project integrated with primary health care activities in South Africa, and an integrated homestead gardening and livestock program in Asia. All four programs achieved their ultimate objective of improving the intake of focus

nutrient-rich foods by target population groups, and the two studies that measured biochemical indicators showed reductions in vitamin A deficiency. Common elements that appear to have contributed to the success of these four programs include a strong behavior change component, careful consideration of local contexts, partnership building with different community members to promote ownership, and a specific focus on women's empowerment. The studies also reaffirm that careful evaluation design is critical but remains a challenge, as does the scaling up of successful pilot programs.

Overall the review documents a wide range of successful agricultural interventions that have contributed to improved nutrition outcomes. In most cases, however, the exact pathways by which impacts on nutrition have been achieved are difficult to track. Most studies document impacts on several intermediary outcomes such as food security, income, or women's empowerment, but without directly modeling these pathways of impact to nutrition outcomes. Because these outcomes are so closely intertwined, it is impossible to determine from this literature the relative importance of the different pathways that connect agriculture and nutrition.

The key lessons learned from this body of evidence are that agricultural interventions are most likely to affect nutrition outcomes when they involve diverse and complementary processes and strategies that redirect the focus beyond agriculture for food production and toward broader consideration of livelihoods, women's empowerment, and optimal intrahousehold uses of resources. Successful projects are those that invest broadly in improving human capital, sustain and increase the livelihood assets of the poor, and focus on gender equality.

THE CHANGING CONTEXT OF AGRICULTURE AND NUTRITION LINKAGES

Over time, changes in the global environment have been modifying how agriculture affects nutrition and have made the need for integrating agriculture and nutrition interventions even more imperative. Four types of global changes are emphasized in the report: changes in agricultural pol-

icity, agricultural technology, food marketing systems, and food consumption patterns. These changes affect the broader context within which nutrition-oriented agricultural interventions are implemented. They also affect each of the pathways through which agriculture affects nutrition, notably consumption of own-production, producer incomes, and food prices.

Agricultural Policy

Agricultural policy in most developing countries has recently undergone a major paradigm shift as part of what is often termed “globalization.” Although the role of the government in food markets remains extensive, governments have dismantled state marketing mechanisms and liberalized trade and investment. The level of taxation or “disprotection” of agriculture has declined over time through trade liberalization in the nonagricultural sectors and changes in exchange rate regimes. Private markets have generally assumed greater importance relative to state intervention, and agriculture’s increased market orientation has changed producers’ incentives, with important effects on food availability and prices.

At the national level, the impact of liberalization on commodity prices will vary across commodities depending on whether the country is a net-importer or a net-exporter of that commodity. The observed pattern of trade in which developing countries are net exporters of high-value, micronutrient-rich crops implies that consumer prices are higher for those products than the prices that would prevail in a closed economy. The reverse would hold for the supply of macronutrients since many developing countries are net importers of grains. Agricultural policy changes can also affect nutrition through the producer income pathway. Again, the overall impact of trade liberalization on income is likely to differ depending on the initial status of the country (as a net importer or exporter), and across farmers within the country depending on whether they are net producers or net consumers.

Agricultural Technology

The growth of agricultural technology has been dramatic over the past 25 years. Developments that carry particularly important implications for food

availability, prices, demand, and consumption are plant breeding and technologies related to food processing and marketing, such as those that maintain a cold-chain from farm to plate. Technologies that increase productivity, such as Green Revolution crop breeding technologies, have significantly reduced food prices of the targeted crops. This in turn has led to significant reductions in childhood malnutrition. Simulation models estimate that without the Green Revolution, the proportion of malnourished children in South Asia would now be 12 to 15 points higher than it is. Improvements in postharvest technology and marketing for fruit and vegetables can also lead to significantly reduced consumer food prices. Changes in technology affect the demand for agricultural labor and thus the income of farm and nonfarm households in rural areas. New technologies can be labor saving or labor enhancing; some may have no effect at all on labor demand. Studies published during the 1990s documented a variety of positive impacts of technology change on labor demand, incomes, food consumption, and diet quality—but failed to exhibit an impact on childhood nutrition. (This was in fact attributed to the failure of increased income and food consumption to translate into better childcare, feeding, and health-seeking behaviors—key elements of improved nutrition.) Biofortification, an agricultural technology that can increase the micronutrient content of staples, may confer large benefits to poor rural populations who have little access to expensive high-quality foods. These improved crops can benefit nutrition through the own-consumption pathway when they are consumed by producers, through the income pathway when they are sold, or through the food price pathway when they increase the availability of micronutrient-rich foods in the marketplace.

Food Marketing Systems

The past two decades have seen a major transformation and consolidation of food retail and an expansion of the food processing and food service industries, especially in middle-income countries and in urban areas of low-income countries. These trends are driven by rising household incomes, urbanization, improvements in transportation, lifestyle changes, and liberalized foreign investment regulations. The rapid growth of supermar-

kets in developing countries in the past 10 to 20 years is increasingly important in shaping food consumption patterns and will most likely affect nutrition through changes in food availability and prices. With the rising availability and generally lower prices of processed foods in marketplaces and food service establishments throughout much of the developing world, a growing proportion of food expenditures go to processed foods relative to fresh food sources. Changes in the composition of agricultural exports also affect the types and price of foods available and current trends show rapid growth in the share of agricultural products that are processed compared with fresh products. This changing pattern of exports has implications for nutrition through the price pathway because it increases the availability of certain foods over others in exporting and importing countries. Whereas consumers in developing countries now consume more processed foods and vegetable oils exported from developed and other developing countries, consumers in industrialized countries now consume more fruits, vegetables, and fish exported from developing countries.

Changing Consumption Patterns

The demand for higher-value, micronutrient-rich foods increases as incomes rise and livelihoods diversify around expanding markets, many of them urban. Increasing incomes and urbanization drive changes in demand that provide food suppliers with market signals that tend to reorient agricultural production away from the cultivation of staples and toward higher-value products. For smallholders in particular, this reorientation is often in effect compulsory, because the viability of farming lower-value staple crops relies on much larger scales of production than are possible on small farms. For food consumers, and especially net food consumers, the shift in consumption away from staples and toward higher-value food sources brings a phenomenon that is generically referred to as the “nutrition transition.” The phenomenon is most pronounced in rapidly growing economies and in urban areas, in which the proportion of food prepared at home declines in relation to the proportion of processed foods consumed in and outside the home. Diets tend to become increasingly energy-dense, and very often excessively so, at the same time that automation, transportation, and

sedentary lifestyles are dramatically reducing the level of physical activity and thus energy requirements. Negative outcomes like obesity, heart disease, and diabetes quickly become endemic, which in turn prompt additional changes in the demand for food. Functional foods that carry health benefits become the focus of advertising and the communication of health-related information, with dramatic effects on the types of foods that are demanded. The trend offers a variety of important opportunities for producers who are able to respond to the changing demand. As consumers manifest greater willingness to pay more for healthier foods, responsive producers find a very real prospect that the downward pressure on prices exerted by increased production may be reversed. However promising this prospect may be, the ability of poor producers to capitalize on the emerging opportunities is contingent on a number of factors, not the least of which is the risk of converting to the cultivation of unfamiliar crops. In the final analysis, much will depend on the success of arrangements like contract farming, which enables poor farmers to link their production with large, often supermarket-led supply chains.

Conclusion

Changes in agricultural policy, technology, markets, and associated changes in food consumption patterns are changing the pathways through which agriculture and nutrition are linked. Today, the more market-oriented nature of agricultural policies means that agricultural technology and markets play a more important role in determining food prices and rural incomes, as more food is consumed from the marketplace and less from households’ own-production. The greater market orientation of food production and consumption has increased the bidirectional links between agriculture and nutrition. Agricultural production remains an important factor contributing to nutritional outcomes, but changing food and nutritional demands are exerting new effects on agricultural production. Agricultural programs with nutritional objectives need to take this changing context into account to ensure that the synergies between agriculture and nutrition are successfully exploited and lead overall to better development outcomes.

INSTITUTIONS

Improving nutritional outcomes is a decidedly multisectoral goal and requires the involvement of several players, including households and public and private sector agents. It also requires the involvement of *government* institutions that formulate public policy and that in so doing influence the settings in which agriculture-nutrition pathways are or are not operationalized. Jurisdiction over food production and food supply is generally assigned to a country's ministry of agriculture. Nutrition, however, is not ordinarily considered a sector but rather a policy issue or area that does not fall cleanly within the jurisdiction of any particular ministry or agency. Health ministries generally assume the most direct responsibility for nutrition, but they have no administrative jurisdiction or influence over agriculture or trade—the most important sector ministries addressing food supply and availability. Common sense may suggest the establishment of a governmental multisector agency to coordinate joint action among these ministries, a course which has been pursued by a number of countries. These coordinating bodies have however seen little if any success in achieving effective cooperation between sector ministries, leaving little empirical basis for assuming that such institutional adaptations actually work. Concerted programmatic coordination between different ministerial-level institutions tends to run headlong into the bureaucratic barriers that divide spheres of responsibility between different line ministries. Bureaucracies in general are organized to rationally divide responsibilities within institutions, not to orchestrate joint collaboration between them. Coordination between different government institutions is therefore problematical, but cannot be dismissed altogether. Possibilities for such collaboration are by no means limited to systematic high-level institutional frameworks. More limited, lower-level opportunities for collaboration to address specific and local issues contributing to malnutrition appear to offer greater promise for effective action. This local collaboration offers the prospect of incrementally improving higher-level coordination of multisectoral action to address food insecurity and malnutrition effectively on a national basis.

LESSONS LEARNED AND NEXT STEPS

Policy makers and practitioners have long aimed to influence nutritional outcomes through agricultural programs. Many of these programs supported commercialization and cash crop production or the production of fruit and vegetables or animal source foods with overall objectives of raising agricultural productivity and household income. The assumption was that agriculture would tackle poverty and malnutrition by increasing food production, lowering food prices, and increasing household income. While food production and household food availability, income, and in many cases food consumption and diet quality increased, childhood malnutrition persisted. This led to the conclusion that increasing agricultural production and income were probably necessary but clearly not sufficient conditions to reducing malnutrition. Far more substantial impacts were achieved when agricultural interventions incorporated nonagricultural components or combined with complementary nonagricultural interventions that addressed other determinants of child nutrition. These other determinants included maternal health-seeking and caregiving practices. Arming women with knowledge about appropriate child feeding practices, the importance of different micronutrients, and the food sources in which those micronutrients are available was a particularly effective way of improving child health and nutrition outcomes.

Incorporating nonagricultural criteria like health and nutrition into the design and conduct of agricultural programs to improve nutrition suggests developing an effective interface between agricultural and other institutions. Yet systematic high-level coordination between different sector ministries is challenging given the bureaucratic barriers that typically divide them. The report therefore examined alternative approaches to formulating a more comprehensive approach for agriculture programs to embrace improved nutrition as a development objective.

The empirical evidence presented in this report focuses on agricultural programs and interventions carried out at the level of local communities. Overall, the review found that the most successful projects were those that invested broadly in improving human capital and sustained and increased the livelihood assets of the poor. The four

key lessons learned about how these programs should be developed and implemented in order to help achieve improved nutrition outcomes are summarized below.

- *Develop and implement agricultural programs that take into account local contexts.* The importance of designing programs that accommodate prevailing agricultural and nutritional conditions has long been recognized and entails developing a sound understanding of producers' priorities, incentives, assets, vulnerabilities, and livelihood strategies. For these programs to benefit nutrition, however, there is also a need to understand and target the major nutritional problems experienced by the target communities an aspect that is usually ignored in agricultural program design and development. Understanding the motives and constraints that affect household consumption decisions is no less important than understanding those that affect production decisions. Cultural norms, for instance, are often key factors determining which household members maintain control over which household resources, and influence such nutritionally vital decisions as the allocation of types and quantities of food among household members. Thus, successful agriculture programs aimed at improving nutrition must first develop an understanding of the economic, social, and cultural factors that determine household decisions concerning livelihood, agriculture production, household consumption, and intrahousehold allocation of resources, as well as the context-specific health and nutrition problems that prevail.
- *Develop and implement agricultural programs that enable and empower women.* The essential role of women in delivering health and nutrition outcomes makes gender an inevitable priority area for agricultural programs and policies that seek to contribute to nutrition. Targeting women in their roles as economic agents and stewards of household food security and health generally entails increasing their access to productive resources and services—an ostensibly straightforward proposition that in reality must take into account and purposefully navigate around a variety of women's constraints, including cultural constraints. The significance of women's education to the health and nutrition of their children is an established axiom of development planning. This education by no means has to be limited to formal education. Communication of information about health issues such as appropriate child-feeding and childcare practices, water sanitation, and food safety issues carries great importance for nutrition by addressing caregiving and health as necessary conditions of good nutrition. Other public information services, including those agricultural extension services that convey information about issues like integrated pest management, likewise have important positive health impacts and many can also be tailored to reach women.
- *Develop and implement agricultural programs that incorporate nutrition outreach and behavior change.* Whether regarded as a resource or a service, the value of information that is directed at behavior change among farmers and consumers presents itself as a salient conclusion of this report. Agricultural interventions that include a nutrition education component will increase the likelihood of positive nutritional outcomes. Those who are armed with information and knowledge about the nutritional significance of the foods they produce and eat are able to make better production and consumption decisions. Nutrition-related education and communication strategies may offer instruction on food preparation and safety and on child-care and feeding practices, as well as on how to recognize and act upon signs of nutritional deficiencies. Here, too, targeting women with health and nutrition information is likely to have a still greater catalytic effect, given their typically closer affiliation with the household and their crucial role as child caretaker.
- * *Provide small producers with help and support to respond to changes in the global environment and especially to the changing food demand.* Anticipating and responding to changing demand is a vital imperative for farmers in general, but among poor farmers in developing countries the stakes are particularly high. A significant part of their production is intended for their households' own consumption, and therefore much of the demand they are satisfying is their own. With respect to the proportion of food

they produce for market, the changing agricultural context has important implications for the prices they are paid for their products, while increasing demand for high-value food sources represents an important opportunity to earn more income. Yet switching to new and unfamiliar crops and producing for foreign markets with stringent food quality and safety requirements is also fraught with risk, and both opportunities and risks need to be addressed by agricultural programs.

This report consists mainly of a review of empirical evidence about past and ongoing cases of agricultural interventions with nutrition-related objectives and more broadly about connections between agricultural production and nutrition. Its analysis of the practical implications of the lessons

learned sheds light on the dynamics and causal relations that agricultural practitioners should take into account when planning programs or providing policy advice that focuses the crosshairs of production goals onto a nutrition-related target or targets. There is by now good reason to anticipate that nutritional aims will come to play more prominently in the calculus by which the value of agricultural programs is rated. Future agricultural programs implemented with nutritional objectives will need to address the real challenge of going to scale and should be carefully monitored and rigorously evaluated to ensure that performance can be continually tracked and improved. The expository account offered in this report, it is hoped, lays the groundwork for more practical work in which the details of applying these lessons operationally can be prescribed.

In a world abundant with food, millions of people suffer from poor nutrition. In some parts of the world, the poor have inadequate access to energy (measured in calories) from food. In these locations, food shortages are often seasonal phenomena, and the quantitative deficit of food energy is generally matched by deficits in food quality reflected in insufficient essential micronutrients including vitamin A, iron, zinc, folate, and many others. Elsewhere consumption among the poor is characterized by monotonous diets in which these micronutrient deficiencies are found despite stable and sufficient intakes of food energy. Still other places see a “nutrition transition” under way in which diets are characterized by excessive intakes of energy, largely from fat, added sugars, and energy-dense processed foods, and in which lifestyles are characterized by generally low levels of physical activity. This combination of excessive energy intake and low activity patterns is associated with overweight and obesity and a variety of chronic diseases including diabetes and heart disease. Together these adverse nutrition outcomes affect some 2 billion people worldwide.

The factors that contribute to malnutrition and poor nutrition outcomes are complex and vary across production and consumption settings. Sector-specific strategies tend to approach nutrition issues along narrowly disciplinary lines and generally disregard contributing factors that fall outside the purview of that particular field. Agriculture’s role as the source of food production makes its significance to nutrition unquestionable. Yet the persistence of malnutrition as a global public health concern despite increasing agricultural production belies any notion that the malnutrition and undernutrition problem can be solved entirely from the supply side by increasing production. Nutrition is intrinsically multisectoral, and strategies to improve nutrition outcomes should seek to purposefully integrate the contributions of relevant disciplines. How agriculture’s necessary input into nutrition issues is to be operationally coordinated with the likewise necessary input of nonagricultural sectors is a more difficult matter. Historically, multisector efforts intended to simultaneously address agriculture and nutrition have often been hindered by institutional barriers and insufficient resources.

Agricultural investments and interventions supported by the World Bank and other international development and donor agencies have seldom explicitly incorporated nutrition-related objectives. The

World Bank itself last examined this issue in 1981 in a study by Per Pinstrup-Andersen, which made a number of recommendations for incorporating nutritional effects into the design and planning of agricultural policies and programs. A recent review of its agriculture and rural development portfolio revealed little or no lending for nutrition issues to be included in agricultural education or extension services. The only nutrition-focused agricultural interventions to receive significant support from international development and donor agencies in recent years involved the still-developing technology of biofortification.

The contexts in which agriculture and nutrition are linked have, moreover, changed since the 1980s (Hawkes and Ruel 2006b). The focus of nutrition as a development issue, and a human development issue in particular, has expanded from an early emphasis on energy-protein deficiency to include micronutrient deficiencies, and more recently extends to the relationship between excess energy intake, poor-quality diets, obesity, and chronic diseases. The agricultural context itself is also changing. Although 75 percent of the world's poor still live in rural areas with poor access to markets and services, fewer people are now dependent on agriculture for their livelihoods and more are connected to markets. The percentage of poor people who live in urban areas in developing countries is growing. Urbanization reflects a migration away from rural, agriculture-based employment and into urban livelihoods. People in cities are less likely to experience undernutrition and more likely to experience the "nutrition transition" toward energy-dense diets high in fats, sweeteners, and highly refined carbohydrates (Popkin 1999). Overall, the processes of global market integration, or "globalization," have increased the market-orientation of the agri-food system worldwide, unleashing dynamics throughout the food supply chain that affect food producers and consumers.

Malnutrition remains an urgent global public health concern. The question of how agriculture can most effectively contribute to improved nutrition outcomes remains unanswered. It is therefore time to revisit what is known and what can be done to improve the synergies between agriculture and nutrition. The potential contribution of agriculture needs to be reexamined, especially in light of the changes the sector has undergone, by reviewing

lessons from past experience and by analyzing current developments and what they mean for future change. This is the purpose of this report.

More specifically, the report seeks to analyze what has been learned about how agricultural interventions influence nutrition outcomes in low- and middle-income countries, focusing on the target populations of the Millennium Development Goals—people living on less than a dollar a day. It also sets out to synthesize lessons from past institutional and organizational efforts to improve the synergies between agriculture and nutrition outcomes. The report identifies a number of developments in agriculture and nutrition that have transformed the context in which nutrition is affected by agriculture. These developments have considerable practical significance for nutrition-related agricultural programs—including the design of those programs that aim to improve nutritional outcomes. Finally, the report sets out a number of practical conclusions that shed light on how agricultural interventions and investments may improve nutrition outcomes in low- and middle-income countries.

WORLD FOOD SECURITY AND NUTRITION SITUATION

The Food and Agricultural Organization (FAO) estimates that in 2000–03, 854 million people worldwide were undernourished, as defined by food intakes that are continuously inadequate to meet dietary energy requirements (FAO 2006). The number included 820 million people in developing countries, 25 million in transition countries, and 9 million in industrialized countries. In developing countries, this represents a decline of only 3 million people since 1990–92. And although significant progress has been achieved in Asia, the number of undernourished people in Africa has been increasing, as shown in table 1.

Food security, a broader concept than undernourishment, necessarily goes beyond the satisfaction of people's energy requirements through sufficient intakes to encompass access to "sufficient, safe and nutritious food to meet dietary needs and food preferences for an active and healthy life" (FAO 1996). A summary of the nutritional situation in the world is presented here in three categories: childhood undernutrition, micronutrient deficiencies, and overweight and obe-

Table 1 Prevalence and Number of Undernourished People in Developing Countries 1990–2003

FAO Region	Prevalence of Undernourished (%) ^a		Number of Undernourished (million)	
	1990–92	2001–03	1990–92	2001–03
Developing countries	20	17	823.1	820.2
Sub-Saharan Africa	35	32	169.0	206.2
Near East and North Africa	8	9	25.0	37.6
Asia	20	6	569.7	524.0
Latin America and Caribbean	13	10	59.6	52.4

Source: FAO 2006.

a. Undernourishment is defined as food intake that is continuously inadequate to meet dietary energy requirements.

sity and related chronic diseases. More complete analyses of these trends are available in the 2006 World Bank report *Repositioning Nutrition for Development* and in the fourth and fifth reports on the world nutrition situation issued by the United Nations Standing Committee on Nutrition in 2000 and 2004.

Child Undernutrition

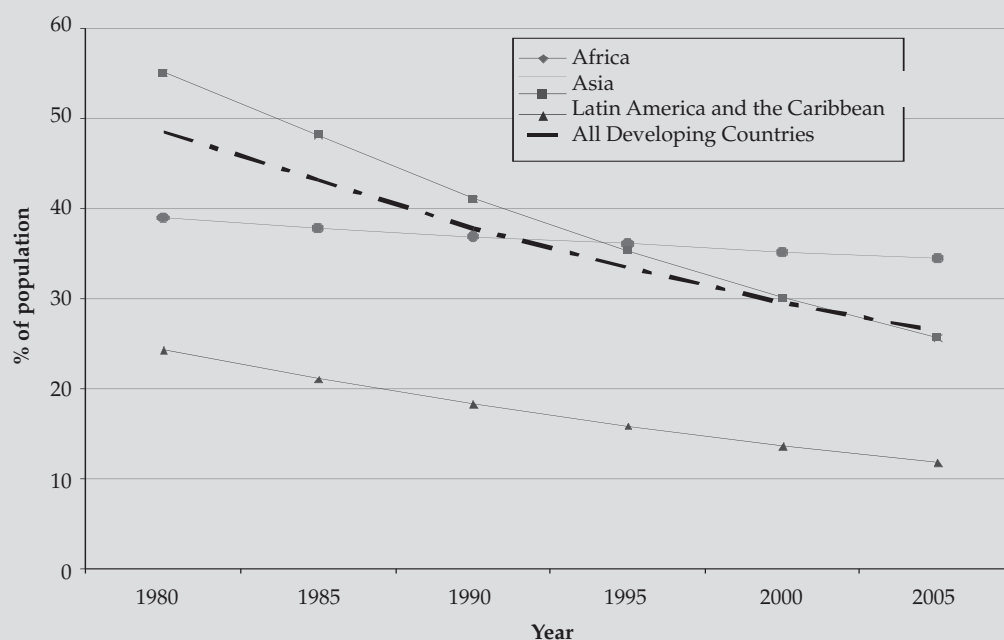
It is well recognized that the most nutritionally vulnerable population groups are pregnant and lactating women, whose bodies must cope with the additional nutritional stresses and demands of pregnancy and lactation, and infants and young children up to age two. The present report addresses these vulnerable groups, but with a greater emphasis on children's nutrition because most of the work linking agriculture and nutrition to date has focused on this age group. Childhood undernutrition is typically reflected in anthropometric indicators such as stunting (low height-for-age), wasting (low weight-for-height), and underweight (low weight-for-age). Stunting reflects the cumulative effects of inadequate nutrition, whereas wasting reflects more recent or acute weight loss. These symptoms are nonspecific and reflect a combination of nutritional deficiencies including protein, energy, and/or micronutrients. They may be seasonal or chronic. Dietary shortages of vitamin A, iodine, iron, and zinc are the most widespread mi-

cronutrient deficiencies and disproportionately affect women and young children.

Childhood undernutrition dropped globally between 1980 and 2005. Stunting now affects approximately one-third of all children in the developing world, compared to one-half in 1980. The proportion of underweight children fell from 38 percent to 25 percent during the same period. Yet there were an estimated 164.79 million stunted and 137.95 million underweight children in developing countries in 2005. Figures 1 and 2 show that most of the reductions in undernutrition since the 1980s have been achieved in Asia and Latin America. In Africa, the number of stunted children decreased, while the proportion and number of those who are underweight increased slightly.

Micronutrient Deficiencies

Vitamin A, iron, zinc, and iodine are the most widespread nutritional deficiencies globally, and they affect women and young children disproportionately. They may or may not overlap with protein and energy deficits. Vitamin A deficiency is widespread throughout the developing world, affecting between 78 and 254 million people, including an estimated 127 million children (UN SCN 2004; West 2002). Shortage of the nutrient in the diet can limit growth, weaken immunity, cause xerophthalmia (an irreversible eye disorder leading to blindness), and increase mortality. Seventy per-

Figure 1 Estimated Prevalence of Stunted Preschool Children 1980–2005

Source: UN SCN 2004.

Note: Preschool children defined as children less than five years of age.

cent of preschool children in Benin and Kenya are subclinically vitamin A deficient, compared to just 5 percent in Venezuela, revealing the wide variability in the condition's prevalence among developing countries (Sommer and West 1996).

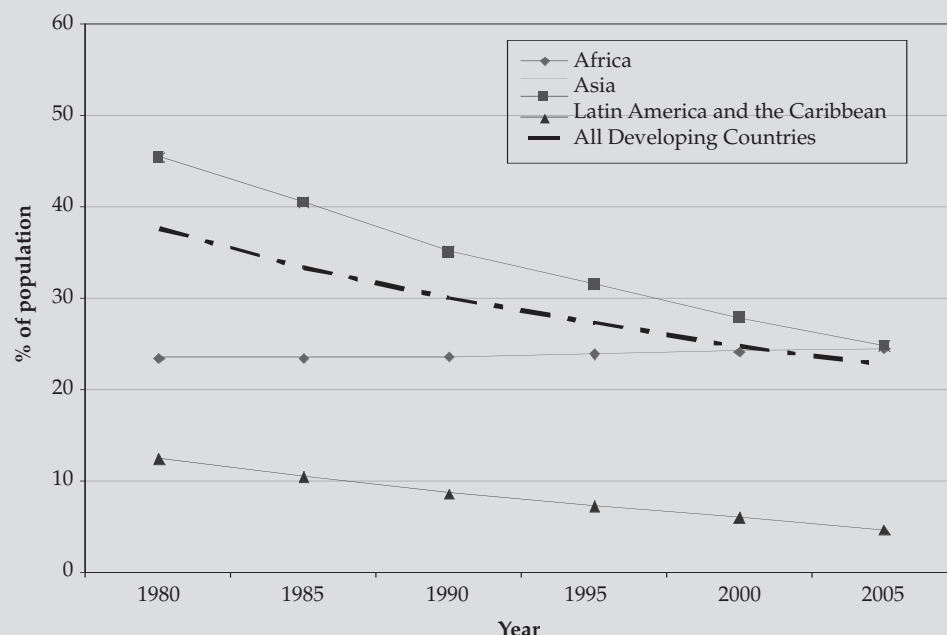
Iron deficiency is estimated to be the most prevalent nutritional deficiency, affecting 4 billion to 5 billion people. The estimated prevalence of iron deficiency among children under five years of age in 80 developing countries in 2004 was 54 percent, as compared to an estimated 34 percent who are vitamin A deficient. Again, the range in prevalence between countries is wide. An estimated 20 percent to 35 percent of children under five years of age are iron deficiency anemic in Latin America and Southeast Asia, compared to an estimated 75 percent to 85 percent in many African countries (Adamson 2004). In young children, iron deficiency may impair growth, cognitive development, and

immune function. In school-age children, it can affect school performance, and in adults it may lower work capacity. Iron deficiency anemia is responsible for tens of thousands of maternal deaths each year (UN SCN 2004).

Iodine and zinc deficiency are also widespread and account for a large share of the poor development, health, and survival outcomes of children in developing countries (UN SCN 2004). Deficiencies of key vitamins and minerals continue to be pervasive, and they overlap considerably with problems of general undernutrition (underweight, wasting, and stunting).

Overweight, Obesity, and Diet-Related Chronic Diseases

A set of very different nutrition-related outcomes affect people whose nutrient intakes exceed their

Figure 2 Estimated Prevalence of Underweight Preschool Children 1980–2005

Source: UN SCN 2004.

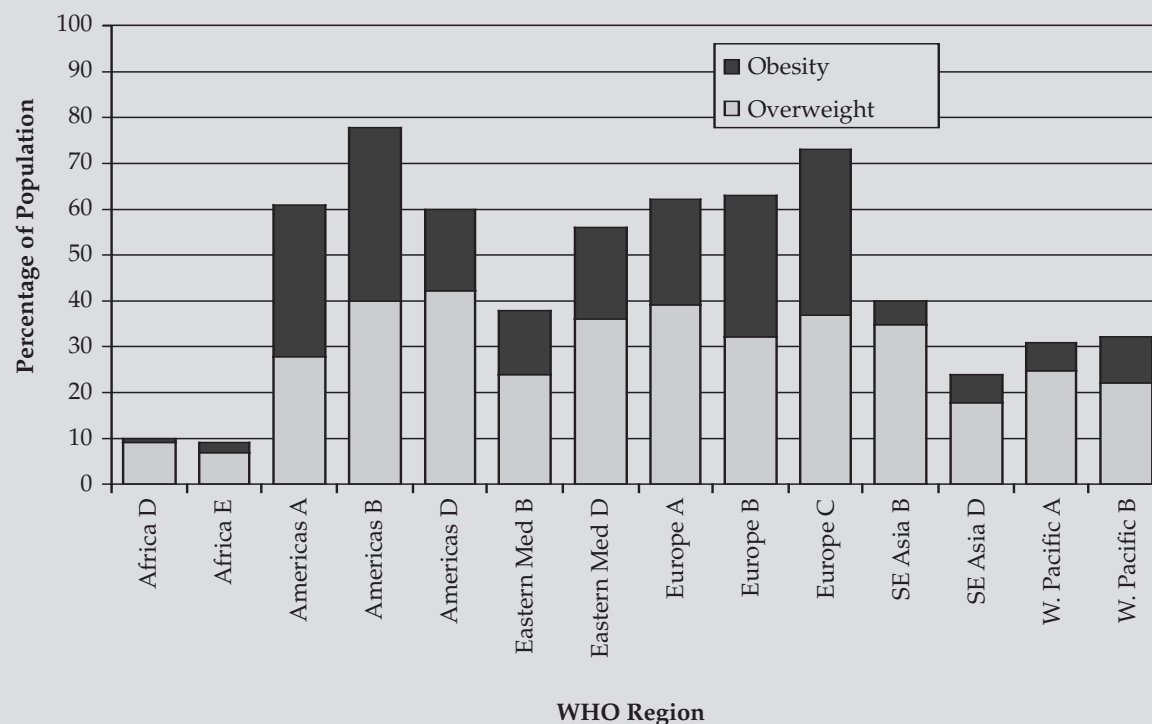
Note: Preschool children defined as children less than five years of age.

energy expenditures, resulting in obesity and a variety of chronic diseases associated with excess weight, including heart disease and diabetes. Among poorer populations in particular, energy-dense, low-quality diets are likely to remain deficient in essential micronutrients. Overweight and obesity are now highly prevalent in every region of the world.¹ The prevalence of overweight children under five is also increasing throughout the developing world. The prevalence of childhood obesity in the developing world increased by 17 percent between 1995 and 2005, whereas in Africa it increased by 58 percent. The reason that Africa is experiencing such an exaggerated trend is not entirely clear, owing to a lack of data, but the rise in prevalence of overweight among mothers is likely to be part of the explanation (World Bank 2006b). The prevalence of overweight is considerably higher in urban areas in the developing world,

but in Latin America, the Middle East, and South Africa, overweight is also higher than underweight in rural areas (Mendez and Popkin 2004). Overall, the World Health Organization predicts that by 2015, approximately 2.3 billion adults will be overweight and more than 700 million will be obese (WHO 2006).

Overweight and obesity are strongly associated with the risk of several chronic diseases, including diabetes, cardiovascular diseases, and several types of cancer. Figures 3 and 4 show trends in overweight by region since the 1980s among adult women and among preschool children. Chronic diseases are the largest cause of death in the world,

¹ Overweight is defined as a body mass index (BMI) (weight/height square) greater than 25; obesity is defined as BMI greater than 30.

Figure 3 Overweight and Obesity among Women 45–59 Years of Age, by WHO Region

Source: Source: James et al. 2004. Data collected between 1990 and 2000.

*Africa D comprises northern and western parts of Sub-Saharan Africa, e.g., Nigeria, Ghana.

Africa E comprises central, eastern, and southern parts of Sub-Saharan Africa, e.g., Kenya, Mozambique.

America A comprises North America and Cuba.

America B comprises the Caribbean and some Latin American countries, e.g., Mexico, Venezuela.

America D comprises some Latin American countries, e.g., Guatemala, Peru.

Eastern Med B comprises much of the Middle East and some of North Africa, e.g., Tunisia, Saudi Arabia.

Eastern Med D comprises countries in the Middle East, North Africa, and Asia, e.g., Egypt, Morocco.

Europe A comprises most of Western Europe.

Europe B comprises some of Eastern Europe and Central Asia.

Europe C comprises the rest of Eastern Europe and Central Asia.

Southeast Asia B comprises Indonesia, Sri Lanka, and Thailand.

Southeast Asia D comprises most of South Asia, e.g., Bangladesh, India.

Western Pacific A comprises Australia, New Zealand, Singapore, Japan, and Brunei.

Western Pacific B comprises China and some countries of East Asia, e.g., Vietnam, and the Pacific Islands.

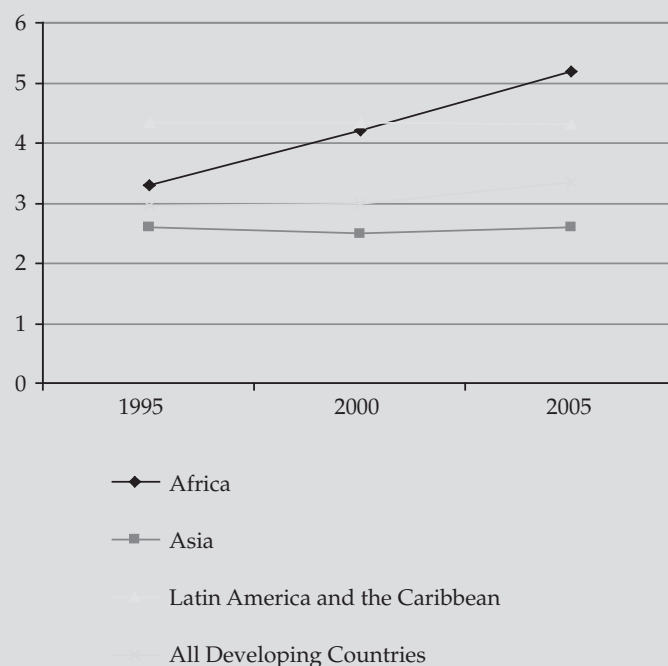
led by cardiovascular disease (17 million deaths in 2002, mainly from ischemic heart disease and stroke) followed by cancer (7 million deaths), chronic lung diseases (4 million), and diabetes mellitus (almost 1 million) (Yach et al. 2004). Although chronic diseases have been the leading cause of death in developed countries for decades, 80 percent of deaths from chronic diseases now occur in developing countries, in which cardiovascular dis-

ease is the leading cause of mortality (WHO 2005). The global prevalence of the leading chronic diseases is projected to increase substantially during the next two decades. The number of individuals with diabetes, for instance, is projected to rise from 171 million or 2.8 percent of the global population in 2000 to 366 million, or 6.5 percent in 2030—298 million of whom will live in developing countries (Wild et al. 2004).

STRUCTURE OF THE REPORT

The background and description of types of adverse nutrition outcomes given in this introduction are followed in chapter 2 by an analysis of the determinants of human nutrition, setting out a number of pathways through which agriculture can potentially affect nutrition. Chapter 3 presents a review of available evidence of how agricultural interventions influence nutrition outcomes. Chapter 4 presents a series of four more detailed case studies of agricultural interventions that had explicit nutrition-related objectives. Chapter 5 examines the changes in agriculture and nutrition that are affecting the operational contexts in which nutrition-focused agricultural interventions are carried out. Chapter 6 focuses on the institutional issues related to the operationalizing agricultural development strategies that have nutritional objectives, primarily at the national level. It maps out the state-level institutions involved with agriculture and nutrition and analyzes the barriers that have posed problems for closer coordination in the past. Chapter 7 draws a set of conclusions as to how agricultural interventions and investments could accelerate improvements in nutrition in low- and middle-income countries.

Figure 4 Estimated Prevalence of Overweight Preschool Children (%)



Source: UN Standing Committee on Nutrition 2004.

Note: Preschool children defined as children under the age of 5.

Determinants of Human Nutrition and the Pathways Linking Agriculture and Nutrition

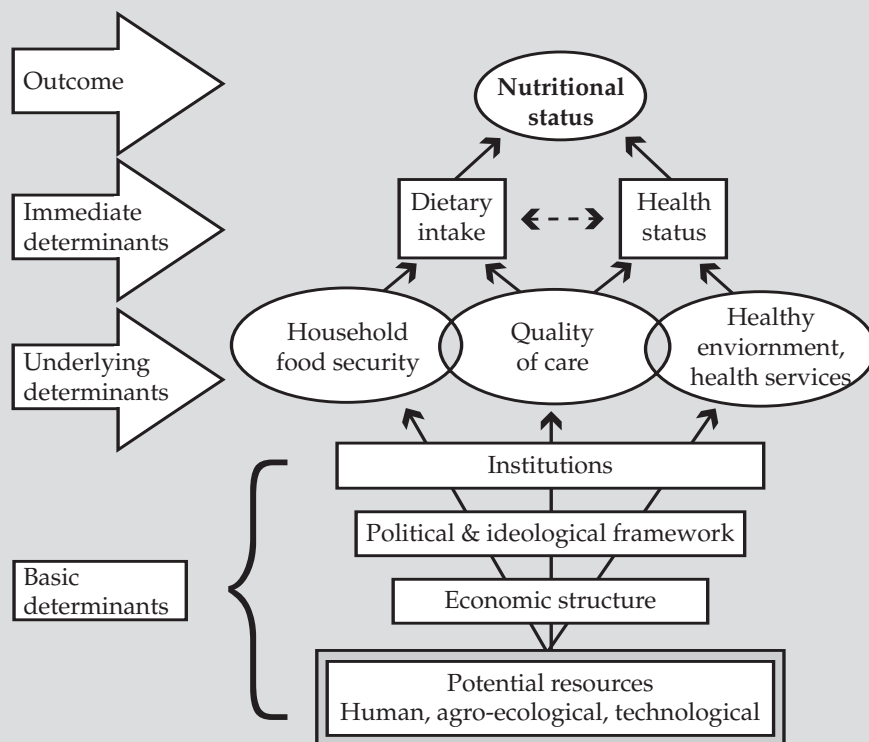
International development agencies have been designing approaches and programs linking agriculture and nutrition to address the problem of malnutrition since the 1960s. The conventional link has been from agriculture to food security. The lack of an explicit indicator of food security led to the use of anthropometric indicators to measure nutritional status. Yet these indicators capture far more than food security as illustrated in a conceptual framework of nutrition developed by UNICEF (UNICEF 1990), (Figure 5).

Food security is just one underlying determinant of nutrition, along with the quality of maternal and child care, the adequacy and use of preventive and curative health services, and whether individuals are living in a healthy environment. The more immediate determinants of nutritional status are dietary intake and health status. The focus of this report is on the connection between agricultural production and dietary intake via food security.

In the 1970s food price spikes prompted alarm and concerns about food availability and brought the term “food security” into the development arena. Programs operated under an assumption that agriculture’s primary role in this equation was to address protein-energy deficiencies by increasing food production and lowering food prices. During the Green Revolution the availability of staple cereals increased globally and prices fell proportionately, yet protein-energy malnutrition persisted. Publications on agriculture-nutrition linkages became critical of what appeared to be an implicit assumption that improved nutrition would follow naturally from the gains achieved through production increases. Box 1 lists the key messages to emerge from these publications during this period and afterward.

In 1981 the World Bank commissioned a report by Per Pinstrup-Andersen titled *Nutritional Consequences of Agricultural Projects: Conceptual Relationships and Assessment Approaches*, which argued that if agricultural development was to better contribute to improving nutrition, nutritional aims would have to be explicitly incorporated into agricultural production decisions. Amartya Sen’s work on famines and the concept of entitlements, together with the failure to achieve real improvements in nutritional outcomes, led food security practitioners to shift their attention to improving poor households’ income and their economic access to food.

Figure 5 Conceptual Framework of the Determinants of Nutritional Status



Source: Adapted from UNICEF 1980.

The change was reflected by the messages emerging from publications produced in the early 1990s (box 1). In particular, the nutritional implications of agricultural commercialization (mainly the shift to cash cropping) were examined. Studies found that even when commercial agricultural schemes increased income, they did not substantially improve child nutrition status, leading to the conclusion that income alone could not solve malnutrition. In the nutrition community, meanwhile, there was a distinct shift in the late 1990s away from the concept of agriculture as an intervention to reduce energy deficiency and increase income and toward the importance of addressing micronutrient deficiencies through agriculture. A conference held in the Philippines in 1999, *Improving Human Nutrition through Agriculture: The Role of International Agricultural Research*, brought together nutritionists and agricultural scientists to assess the role that agricultural research could play

in alleviating micronutrient malnutrition, including through emerging technologies such as biofortification (Bouis 2000). This reflected a shift in emphasis in nutrition programs in general. "Food-based" strategies were developed to promote micronutrient intake, such as through homestead gardening. At the same time the food security definition evolved from a focus on availability and economic access to include food utilization, encompassing diet quality and care issues. This culminated in the 1996 World Food Summit definition of food security:

Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life.

World Food Summit Plan of Action

Box 1 Messages from Publications on Agriculture and Nutrition, 1970s–2000s

- *Scrimshaw and Behar 1976*—protein-energy malnutrition persists despite the major improvements in agricultural technology that have increased food production.
- *Pinstrup-Andersen 1981*—because malnutrition is caused by a variety of factors, simply expanding food production per se is insufficient to solve global nutritional problems. Increased food production and income are currently the explicit goals of agricultural development projects; nutrition is only an implicit goal. If agricultural development plans and strategies are to contribute to solving nutrition problems, they should include an explicit goal of reducing protein-energy malnutrition.
- *FAO (Food and Agriculture Organization) 1982*—if development efforts are to reduce malnutrition effectively, nutritional considerations must be incorporated into projects of agricultural and rural development.
- *Pinstrup-Andersen et al. 1984*—past agricultural research has facilitated a rapid increase in food production in developing countries, but that has not been sufficient to address nutrition needs by itself; nutrition should therefore be considered explicitly in decisions about the design of agricultural research in four key ways: focusing on specific crops, considering the effects of the intervention on the overall diet; specifying the desired agricultural technology; and adapting farming systems to meet nutritional goals in low-income farm households
- *Pacey and Payne 1985*—the targeting of nutritionally vulnerable groups is needed to design agricultural interventions to support nutrition, such as through high-energy, low-cost foods and drought- and pest-resistant crop varieties.
- *Kennedy and Bouis 1993*—agriculture affects nutrition through three main pathways: income, sanitation and health environment, and time allocation.
- *DeWalt 1993*—impacts of agricultural commercialization on food consumption and child nutrition are mixed and highly determined by control of production/income, allocation of household labor, maintenance of subsistence production, land tenure, and pricing policies for food/non-food crops.
- *von Braun and Kennedy 1994*—negative effects of agricultural commercialization on nutrition are not typical, but even when cash cropping increases income, it does not decrease child undernutrition; thus increased income cannot solve malnutrition by itself.
- *Bouis 2000*—breeding nutritionally improved crops can play an important role in alleviating malnutrition.
- *Ruel 2001*—although evidence is still weak, some food-based agriculture strategies have been successful in reducing iron and vitamin A deficiency, especially when they were combined with effective behavioral change and communication interventions and had an explicit focus on women's empowerment.
- *Pretty and Hine 2001*—the environmental and health problems associated with agriculture affect health and nutrition; sustainable agriculture projects can have positive effects on health and nutrition such as through decreased pesticide use and greater social capital among women.
- *Allen 2003*—increasing the production of animal source foods is a potentially sustainable solution to micronutrient malnutrition; the possible adverse effects of excessive increases in animal source food consumption on fat and energy intakes must also be addressed.
- *Johnson-Welch 2002*—taking a gender-sensitive approach to agricultural interventions can strengthen the positive impact of agriculture on nutrition.
- *Kataki and Babu 2002*—nutrition should be considered when agricultural technologies are developed.
- *Berti et al. 2004*—investing in the target population broadly, rather than narrowly through agriculture, improves the effectiveness of agricultural interventions; investing broadly in five types of capital (natural, physical, social, human, and financial) increases prospects for nutrition improvement.

Yet even today the conception of “food security” employed by the agricultural community often neglects the nutritional aspects of this more complete definition and in so doing misses important opportunities to contribute to improved nutrition outcomes. This persistent neglect was a driver in undertaking the work leading to this report. The 1990s also marked a shift to greater focus on women, including intrahousehold resource allocation issues in agriculture and income control and caregiving. In the early 2000s efforts focused on the role of women and on the importance of combining agriculture interventions with nutrition education and behavior change to maximize their impact on nutrition (box 1). These complementary interventions and their focus on empowering women had the objective of not only increasing food availability and access, but also of ensuring appropriate child-feeding, childcare, and health-seeking practices to improve nutritional outcomes.

PATHWAYS LINKING AGRICULTURE TO NUTRITION

There are several pathways through which agriculture can contribute to improved nutrition. The agriculture-to-nutrition pathways can be characterized along a continuum between the most direct and the least direct, the most direct being characteristic of subsistence production, the least direct reflecting the macroeconomic effects of agricultural growth on national—and indeed global—populations. Particularly in the case of households that produce principally for their own consumption, food and nutrient consumption is directly affected by the specific foods the households themselves produce. This relationship becomes more and more complex as production becomes more market oriented.

Agriculture can also affect nutrition through affecting health in general. Good nutrition is intuitively a precondition for good health, but the relationship runs both ways. Good health is also a precondition for good nutrition, enabling people to metabolize the nutrients they digest. Thus, if agricultural interventions support positive health outcomes—by providing conditions conducive to the reduction of infectious diseases, for instance—nutrition outcomes can be improved. Agricultural interventions to improve food safety and reduce the incidence of food-borne diseases can, for example,

help improve nutrition by reducing diarrheal diseases. These broader links between agriculture and health are beyond the scope of this report but were discussed in a recent study by the International Food Policy Research Institute and a special journal issue on agriculture and health linkages (Hawkes and Ruel 2006a; Hawkes et al. 2007).

- Five pathways linking agriculture with food consumption and human nutrition along the food supply chain are described below:
- Increased consumption from increased food production
- Increased income from the sale of agricultural commodities
- Increased empowerment of women as agents instrumental to improved household food security and health and nutrition outcomes
- Reductions in real food prices associated with increased food supply
- Agricultural growth, leading to increased national income and macroeconomic growth and to poverty reduction and improved nutrition outcomes

The pathways are archetypal, representing model forms that in reality are by no means self-contained or mutually exclusive. Subsistence production, for instance, generally takes place alongside production for sale because few households are self-sufficient in food and because food is not the only requirement that must be met. Income is therefore very important even among households that produce principally for their own consumption. The income and price pathways are likewise overlapping in that the price reductions resulting from increased food supply are given in real terms and as such serve to raise real income.

Pathway 1: Increased consumption from increased food production (production-for-own-consumption). In cases in which the degree of market orientation is low, food consumption is strongly influenced by the level and pattern of agricultural production. The resource endowments of the households (such as land and labor) along with the available technology determine the level of production of different crops, which, in turn, affects the consumption patterns of the households. This agriculture-consumption linkage is particularly relevant in the case of subsistence or semisubsistence households.

Increases in production can lead to greater food availability and consumption at the household

level. This, in turn, can increase the food intake of young children, who are most at risk of malnutrition, assuming that intrahousehold allocation of food is equitable and takes into account their particular needs. The type of food produced influences whether increases in production will affect mostly diet quantity (energy intakes) or diet quality (micronutrient intakes). Staple foods can contribute significantly to alleviating energy (calorie) gaps, whereas fruits and vegetables, dairy, eggs, fish, and meat products can make key contributions to alleviating gaps in essential micronutrients such as iron, zinc, and vitamin A. Animal source foods and fruits and vegetables make staple foods more palatable, thus leading to overall greater food intake. Animal source foods themselves are also rich sources of energy and protein. Some proportion of the food produced may very well be intended for sale in local markets. Some households may, for instance, meet their staples requirements themselves while depending on markets for other products such as fruits and vegetables. Others may rely mainly on home gardens for fruits and vegetables. Whatever role production-for-income plays in this scenario is secondary to the principal purpose of producing food for the household's own food requirements.

Pathway 2: Increased income from the sale of agricultural commodities (production-for-income). As the market orientation of agricultural households increases, the "production-for-own-consumption" pathway just described declines in significance. Rather, income from the sale of surplus production now assumes a primary role, while production for the household's own consumption becomes supplemental. And, rather than desirability for consumption, ability to sell becomes a principal criterion influencing the foods produced. Increases in income can in turn translate into improvements in household food security and food consumption as well as individual food intakes.

However, additional income often has little or no effect on energy intakes because households tend to shift their consumption to purchase higher-quality, more expensive foods that do not necessarily provide more energy. Staple food producers, for instance, may use the income earned from the sale of their produce to buy fruits, vegetables, meat, and fish, and their households may consume these as substitutes for some proportion of the staples they consume. This substitution may significantly

improve the micronutrient content of their diet, without necessarily increasing energy intakes. Of course, the extent of the nutritional benefits relies on the nutrient content of the higher-value substitute food; but it also relies on how well the substitutes offset existing nutritional deficits within the household. The distribution of different types of food among different individuals in the household, and among the more nutritionally vulnerable individuals in particular, is also a vital determinant of nutrition outcomes. The distribution of nutrition and other health-related benefits in the household is a function of often complex decision-making processes strongly determined by culture and traditions. The people with the greatest influence over these decisions tend to be those who control household resources. In the production-for-own-consumption scenario, these resources center on control over the household's basic resource endowment of land, labor, and capital. In the production-for-income scenario, the most important resource tends to be income, and the most important decision makers are those who control income flows. Thus who controls the income is critical—and in part explains why women are so vital in influencing the pathway between agriculture and nutrition.

Pathway 3: Empowerment of women agriculturists. Studies from Africa, Asia, and Latin America clearly show that women's income—and level of control over income—has a significantly greater positive effect on child nutrition and household food security than income controlled by men (Quisumbing et al. 1995; Katz 1994; Hoddinott and Haddad 1994). Women have consistently been shown to be more likely than men to invest in their children's health, nutrition, and education. Thus, agricultural interventions that increase women's income and their control over resources can dramatically increase the potential for positive child nutrition outcomes and health outcomes. The positive effects of increases in women's income on childhood nutrition moreover appear most pronounced among the lowest income groups.

In their roles as agricultural producers and income earners, as well as in their roles as caregivers, women who are reached by communication and education services that relay information on health and nutrition issues appear to be particularly effective agents in delivering improved nutrition outcomes. These roles include child and

elder care, food production, food preparation, water collection, and a variety of income-generating activities, all of which have the potential to contribute to improved nutrition. Thus, the incorporation of a gender equity dimension in agriculture programs and the consideration of women's multiple roles and constraints must be addressed for agricultural programs to achieve positive nutrition impacts.

Pathway 4: Lower real food prices resulting from increased food production. Increased food production can reduce food prices, thereby raising the real income of people who purchase this food in the marketplace. Food prices are also affected by national food availability, which is a reflection of imports and exports as well as production. Lower food prices, in turn, can increase household food security and raise energy and micronutrient consumption.

Changes in food prices are largely driven by changes in the technologies and marketing channels employed by producers. Together, changes in technologies and markets affect the cost of production and, often (but not always), consumer prices. Lower retail prices are likely to benefit consumers more than the agricultural households selling the food, but even so, the impact of lower prices on the net incomes of the agricultural households will depend on new costs of production and the elasticity of demand. The most common example of this link is the effect of Green Revolution technologies on the price of grains.

Pathway 5: Macroeconomic growth arising from agricultural growth. Agricultural growth can theoretically lead to broad improvements in nutrition simply by virtue of its contributions to macroeconomic growth and national income. Increases in agricultural productivity have been and remain important drivers of sustained economic growth, particularly among countries in relatively early phases of economic development. Some evidence suggests that the growth in production results in lower food prices, higher real wages, and a related reduction in poverty rates. In theory, as outlined in the food price pathway described above, reduced food prices allow greater access to food, resulting in better nutrition for the general workforce while also freeing additional household resources from food and other expenditures, to savings and productive investments. Recent evidence confirms that growth in agricultural productivity is important for poverty reduction. A cross-country analysis published in 2002 found that a 1 percent increase in agricultural yields effectively decreases the percentage of a country's population living on less than a dollar a day by 0.64 percent to 0.91 percent, with a slightly higher reduction for African countries (Thirtle et al. 2002). Overall, however, the economic growth-to-malnutrition relationship is modest. A doubling of gross national product (GNP) per capita in developing countries has been associated with a much more modest reduction in childhood undernutrition—on the order of only 23 to 32 percent (Haddad et al. 2003).

The Impact of Agriculture Interventions on Nutrition Outcomes

Outlined in the previous chapter are the *potential* pathways linking agriculture and nutrition. But what is the evidence documenting the actual contribution that agriculture has made to nutrition outcomes via these pathways? This chapter reviews this evidence, focusing on the first three pathways: increased consumption from increased food production, increased income from the sale of agricultural commodities, and empowerment of women agriculturists. Identifying evidence on the latter two pathways—the effect of lower food prices and agricultural growth—proved much more difficult, given that there is little documentation of the nutrition outcomes of these changes at the household or individual level.

The review is based on a systematic search of recently published literature and a limited search of unpublished documents, as well as personal contacts with project officers and international agency staff. The search centered on studies of agriculture interventions that had evaluated individual-level nutrition outcomes, such as child nutritional status, individual food or nutrient intakes, and diet quality.² It drew on previous reviews (Peduzzi 1990; Soleri et al. 1991a, 1991b; Gillespie and Mason 1994; Ruel 2001; and Berti et al. 2004) with the purpose of updating and expanding on them. Much of the analysis related to animal source foods was taken from Leroy and Frongillo (forthcoming). A description of search methods and results is provided in the appendix.

“Interventions” are defined broadly to mean changes purposefully introduced into an existing agriculture system to promote new technologies, management practices, production and marketing methods, and other aims that may or may not include components designed to improve nutrition. Those that do entail explicit nutrition objectives are emphasized in this report because these interventions are more likely to document nutrition outcomes. The nutrition outcomes themselves are treated in terms of the following.

- *Household-level food consumption*, which includes household-level consumption of foods and food groups, or energy (calories), and household expenditure on foods and food groups

2 Other types of agricultural interventions, such as nonfood crops or oil seed crops or technology-based rather than crop-based interventions, were excluded from the review because they typically fail to examine nutrition impact.

- *Individual food and nutrient intake*, which includes intakes of macro- and micronutrients and of foods rich in specific micronutrients that are the focus of interventions such as those addressing vitamin A and iron deficiencies
- *Nutrition status*, which includes anthropometric indicators, such as height, weight, and body mass index, and micronutrient-specific indicators, such as serum retinol (indicator of vitamin A status) and hemoglobin (indicator of iron status)

THE NUTRITIONAL IMPACTS OF AGRICULTURAL INTERVENTIONS

Interventions involving staple foods. The only agricultural interventions involving staple foods that have been evaluated from a nutritional perspective concern agricultural commercialization—the conversion from staple subsistence food production to commercial food production. Although the evaluations had assessment of impacts on nutrition outcomes as an objective, the interventions themselves were not designed to affect child nutritional status per se; objectives were more general and aimed at increasing food production incomes for farm households, or both. The evaluations thus measured the interventions' impact on nutrition outcomes through the production-for-income pathway (indirectly, agricultural commercialization may also have had indirect effects through the agricultural growth and price pathways).

Some early conceptual reviews of links between agricultural commercialization and nutrition had suggested the potential for negative impacts, although some of these examples related to conversion to nonfood crops (Fleuret and Fleuret 1980). One early review showed mixed effects on nutrition, some negative and some positive, but also identified methodological issues that constrained interpretation and comparison (von Braun and Kennedy 1986). Given these uncertainties, the authors designed and undertook a series of microlevel case studies that included assessment of nutrition outcomes as an explicit objective (von Braun and Kennedy 1994). The study's focus was on the impact of commercialization on energy intakes rather than on diet quality or micronutrient intake and was therefore consistent with the then-

prevailing idea that energy intakes were the primary constraint in the diets of the poor (McClaren 1974; Waterlow and Payne 1975). Still, shifts toward more diversified diets were documented in instances in which they occurred. These studies also reported results disaggregated by income group and examined the role of control of income by women as opposed to men.

Results from these and closely related studies were synthesized, yielding a series of conclusions that are summarized in table 2 (DeWalt 1993; Kennedy et al. 1992; von Braun and Kennedy 1994). The principal results did not differ substantially between case studies of the commercialization of staple food crops versus other cash crops. In sum, the case studies documented fairly consistent positive impacts on focus crop production, household income, and food expenditures, but no substantial impacts on young child nutritional status (the main indicator assessed across studies). In one case in which subsistence food production was not maintained, outcomes were worse. DeWalt (1993) concluded that a focus on commercialization per se was misplaced and that impacts on food consumption and child nutrition were determined by control of production and income, allocation of household labor, maintenance of subsistence production, land tenure, and pricing policies for both food and nonfood crops. Kennedy et al. (1992) also attributed the lack of impact on child nutritional status to the generally high levels of morbidity observed in project areas.

- Overall, the authors made the following nutrition-related conclusions:
- Generally, participation in cash-crop schemes resulted in increased household income.
- Increases in income were accompanied by increases in food expenditures, but impacts on consumption were also dependent on changes in relative prices.
- Dietary energy intakes increased in most cases but decreased in some, as food expenditures shifted to more expensive items such as meat and fruits; potential improvements in diet quality were suggested but not quantitatively assessed.
- Increases in women's income were documented in some studies and were generally linked to increases in household energy consumption; this effect was most pronounced among the lowest income groups.

Table 2 Key Results from Selected Studies of Agricultural Commercialization

Country Crop References	Intervention or technological change	Study design Concern with methods	Differences in income ^a	Differences in household energy consumption ^a	Differences in individual energy intakes and nutritional status	Other key results
West Kenya Irrigated rice	2 rice irrigation schemes. Irrigated land was expropriated and redistributed to smallholders for rice production only.	Cross-sectional survey comparing	Total incomes were similar across all four groups, but sources of income were least diverse for resident tenants and most diverse for individual rice growers.	Household energy consumption increased with increasing diversity of income sources.	Child energy intakes were lowest and nutritional status was substantially worse among resident tenants. Other groups fared better and were similar.	In-depth follow-up study among resident tenant households revealed higher per capita food expenditures from income controlled by women.
Niemeijer and Hoorweg 1994 ^b	Initially, all tenants lived on scheme but eventually some moved off scheme.	Resident tenants Nonresident tenants Individual rice growers Non-rice growers				
Niemeijer et al. 1988 ^d	No livestock and only small rain-fed plots on scheme.	No randomization and no control for selection bias				
Rwanda Potatoes	Expansion of potato production in former forest reserve, allowing access to additional land for food production. During reforestation, to keep weeds down, potato production was allowed. However, potato cultivation expanded rapidly and uncontrollably.	Cross sectional survey comparing Farms with and without access to "extra" forest reserve land under potato (monocropped) No randomization and no control for selection bias	Potatoes grown on "extra" land were the only crop marketed to a significant degree, but the amount sold varied from 8% to 45% based on wealth quartile; potato production expanded rural wage labor market.	A 10% increase in income was associated with a 5% increase in energy consumption. A lower degree of commercialization raised energy intakes over and above price and income effects.	Increases in household energy consumption were associated with better child nutritional status, but that effect was very small. Child nutritional status was more strongly related to health and sanitation.	Female-headed households consumed more energy (per unit); this effect was strongest in poorest households and did not hold in wealthiest.
Blanken et al. 1994 ^b						
(von Braun et al. 1991) ^c						
Zambia Hybrid maize	Introduction of hybrid maize. A number of different varieties were introduced over a period of years.	Repeated household surveys comparing Households in high and low adopting areas, as well as adopters and non-adopters	Incomes were 33%–45% higher in high adoption areas whether household adopted or not; incomes of adopters were	Per capita consumption of energy and other nutrients followed same pattern as income (higher intakes among adopters and in high adoption areas)	Results for child nutritional status were mixed: Higher weight but lower height in high adoption areas (young children) and lower weight among	(continued)

Table 2 Key Results from Selected Studies of Agricultural Commercialization, Cont.

Country Crop References	Intervention or technological change	Study design <i>Concern with methods</i>	Differences in income ^a	Differences in household energy consumption ^a	Differences in individual energy intakes and nutritional status	Other key results
		<i>No randomization; authors addressed selection bias by comparing high and low adoption areas, as well as adopters/nonadopters</i>	25% higher than nonadopters		older children. In adopting households, young child height was slightly higher but weight and height were lower among older children	
The Gambia Irrigated rice von Braun et al. 1994 ^b von Braun 1988 ^d	Large-scale rice irrigation scheme. Explicit attempt to maintain traditional use rights of women farmers through giving women priority during registration of plots. Production technology in the scheme is heterogeneous with varying levels of water control.	Repeated household surveys in area of new state-owned, large-scale rice irrigation scheme, with 4 production systems: Traditional swamp rice Small pump irrigation Partial water control (rain or tide) Central irrigation drainage <i>No randomization; authors explored determinants of adoption.</i>	New technology resulted in substantially increased yields and allowed a second crop, but did not have large impact on marketed surplus. Substitution effects in labor allocation meant that increased rice production was accompanied by decreases in other cereals and groundnuts (−\$0.64 per \$1.00 rice).	Consumption (energy) increased with expenditure quartile in both wet (hungry) and dry seasons. A 10% increase in expenditure was associated with a 5% increase in energy (wet season). Consumption was not correlated with household cereal production, but was correlated with women's share of cereal production	Women's seasonal weight fluctuations were buffered in households with greater access to new rice land. Child height was lowest in the lowest expenditure quartile (Q) but similar across Q2_Q4. Child weight increased with household energy intakes; access to new rice land did not have other independent effects, positive or negative.	Traditional swamp rice was a "women's crop"; scheme sought to ensure women's access to new project rice land; however, holding title to land did not ensure control of new resources. Women's control of production and income was decreased for new higher input and higher-yielding rice, resulting in a de facto shift of resources and control.
Mexico Sorghum DeWalt et al. 1990 ^d	Adoption of sorghum production in areas formerly dominated by subsistence agriculture (maize and beans); sorghum production	Ethnographic methods (participant observation and informal interviews) followed by a household survey in four communities in which sorghum	Incomes were highly diversified. Access to good quality and irrigated land	(Neither food consumption nor dietary intake were measured.)	There was no relationship between sorghum production and child nutritional status. Income was associated with child nutri-	(continued)

Table 2 Key Results from Selected Studies of Agricultural Commercialization, Cont.

Country Crop References	Intervention or technological change	Study design <i>Concern with methods</i>	Differences in income ^a	Differences in household energy consumption ^a	Differences in individual energy intakes and nutritional status	Other key results
	increased to meet increasing demand for livestock feed.	was produced as a cash crop. Communities represented range of ecological conditions, landholding size, irrigation as well as access to credit, technical assistance, and markets.	determined income, rather than participation in cash cropping.		tional status, but only weakly.	
		No randomization.				

Source: Authors.

^aIncome and household consumption expressed per adult equivalent unit.

^bIncluded in von Braun and Kennedy 1994.

^cIn Kennedy et al. 1992.

^dIn DeWalt 1993.

- Overall, participation in cash-cropping schemes did not have a significant impact—negative or positive—on young child nutritional status.
- Children's morbidity levels were generally high and not affected by the schemes and were interpreted to be a major constraint to improving child nutritional status.

Evidence from this set of studies suggests that cash cropping was often associated with greater household income, including, in some cases, greater income controlled by women, as well as greater food expenditures. This usually translated into greater household-level energy intake, but sometimes households shifted to more expensive sources of energy. When this shift occurred, it may have resulted in greater dietary diversity, which is generally a sign of improved overall diet quality, but the studies did not specifically assess this aspect. Impacts on child nutritional status were limited and mixed. The studies therefore suggest that although agricultural interventions that promote commercialization may effectively increase income and food expenditures, they are not sufficient to improve childhood nutrition if they are not complemented by interventions that specifically address other determinants of child nutrition such as improved health, diet quality, child feeding, and other caregiving practices.

Interventions involving fruits and vegetables. Despite the existence of a wide variety of fruit and vegetable production systems, only homestead garden production systems have been implemented and evaluated with an explicit nutrition objective. These primarily target the first pathway, increasing own production for consumption, with a secondary pathway of income increases from sales of higher-value products.

Homestead gardens take a wide variety of forms, in backyards, farmyards, kitchens, containers, small patches of available land, vacant lots, on rooftops and tabletops, and along roadsides and the edges of fields. They are generally close to a house and source of water and are managed by family members using low-cost inputs. Their products include fruits, vegetables, herbs, condiments, and sometimes secondary staples like legumes and sweet potatoes, most of which are grown for household consumption. The nutrition impacts of homestead gardens have been relatively well documented. This section draws on previous reviews,

starting with the VITAL reviews and then reviews by Gillespie and Mason (1994), Ruel (2001), and Berti et al. (2004).

In 1990 and 1991 the USAID-funded Vitamin A Field Support Project (VITAL) carried out an assessment of past and then-current household garden interventions and their impacts on nutrition outcomes. The aim was to inform the planning of future research and initiatives. Focusing on the effects of homestead gardens on the intake of vitamin A-rich foods and improving vitamin A status, the review yielded a number of recommendations on design, targeting, and evaluation of homestead gardens as a means of strengthening their nutritional impact. The main recommendation was that interventions should focus on women (through the female empowerment pathway) and provide nutrition education services to promote appropriate processing, storage, and cooking techniques of vitamin A-rich foods. They should also promote a diverse variety of vitamin A-rich foods to meet both subsistence and marketing needs and take into account cultural preferences when foods to be introduced are selected.

A review by Gillespie and Mason published in 1994 considered 13 programs aimed at improving diet quality, seven of which included homestead gardening. Four of these were combined with social marketing activities, and all four exhibited a number of indirect benefits such as increasing women's income and social status. Yet only one project, carried out in Bangladesh, showed a positive effect on vitamin A status in addition to increased energy intakes and improvements in the economic status of women. A summary of the evaluation findings of horticultural and nutrition projects is presented in table 3.

The results of more recent evaluations included in the reviews by Ruel (2001) and Berti et al. (2004) are summarized in table 3. The Ruel review published in 2001 found that the interventions that did not include a nutrition education component (generally those conducted before the mid-1990s) failed to achieve significant impacts on nutritional outcomes. Subsequent interventions that incorporated education, social marketing, and mass media campaigns together with homestead garden initiatives did demonstrate impacts. The main conclusion of the review was that homestead gardening combined with effective promotional and educational interventions have the potential to improve the nu-

Table 3 Summary of the Evaluation Findings of Horticultural and Nutrition Projects

Country and References	Type of intervention	Design	Nutrition impact assessed	Other impact assessed
Bangladesh ^{R,B} Greiner and Mitra 1995	Homestead gardening with provision of seeds, farming education, and nutrition education	Pre-post, with control	Slight decrease in night blindness, indicating improved vitamin A status	Increase in percentage of households growing vegetables and fruit in both treatment and control and increased knowledge of function of vitamin A
*Bangladesh ^{R,B} HKI/AVRDC 1993	Homestead gardening with vegetables, training on agriculture, provision of seeds, nutrition education	Pre-post, with control	Improvements in stunting and in underweight	Increase in vegetable production, size of plot cultivated, year-round availability of vegetables, income, women's control over income, vegetable consumption per capita, children's vegetable intake. Intervention children had fewer respiratory infections.
Bangladesh ^R IFPRI et al. 1998	Vegetable production, fishponds, and credit and agricultural training	Pre-post, with 3 groups: fishponds, vegetables, control	No change in hemoglobin in any group, implying no change in iron status	Increased production of fish and vegetables. No increase in consumption of fish in fishpond group. Increase in vegetable intake in vegetable group.
Ethiopia ^{R,B} Ayalew et al. 1999 ^a Ayalew et al. 1999 ^b	Training on agriculture, food preparation sessions, and provision of seeds, health, and nutrition education	Pre-post, with control	Lower prevalence of clinical signs of vitamin A deficiency in treatment area	In treatment area more gardens and better knowledge, attitudes, and practices (KAP) about vitamin A and clinical eye signs of deficiency. More diversified diet, higher vitamin A food frequency scores.
Guatemala ^B Phillips et al. 1996	Provision of seeds, extension services, and nutrition education for the promotion of vitamin A-rich foods	Pre-post, with control	No data collected on nutrition indicators (only dietary indicators)	Control children, who are without gardens with vitamin A-rich vegetables, have more vitamin A deficiency.
India ^R Chakravarty 2000	Homestead gardening and nutrition and health education	Pre-post	Decrease in ocular signs/symptoms of vitamin A deficiency	Increase in percentage of households growing vegetables. 40% of households sold 10%–25% of produce. Better knowledge, attitudes, and practices on vitamin A, and weekly intake of vitamin A-rich garden produce more than doubled.

(continued)

Table 3 Summary of the Evaluation Findings of Horticultural and Nutrition Projects, Cont.

Country and References	Type of intervention	Design	Nutrition impact assessed	Other impact assessed
Indonesia ^K de Pee et al. 1998	Social marketing with mass-media and 1-on-1 communication to increase intake of targeted vitamin A-rich foods	Pre-post	Increased serum retinol with increased egg consumption, dose-response relationship indicating improved vitamin A status	Increased percentage of children and mothers consuming at least 1 egg in previous week; increase in amount of vegetables prepared/person/day and in vitamin A intake from eggs and plants
Kenya ^{K,B} Hagenimana et al. 1999	Introduction of a new variety of sweet potatoes and training in food-processing techniques; nutrition education	Pre-post, with control	No data collected on nutrition indicators (only dietary indicators)	Higher vitamin A food frequency scores for children in intervention versus control group
Nepal ^{K,B} CARE/Nepal 1995	Homestead gardening, irrigation, agriculture extension, seeds	Pre-post	Deterioration of nutritional status of children during study (no control)	Increase in percentage of households producing vegetables. Insufficient Vitamin A intake for mothers and children pre and post.
Niger ^R Parlato and Gottert 1996	Promotion of home production, multimedia education campaign promoting consumption of vitamin A-rich foods	Pre-post	No data collected on nutrition indicators (only dietary indicators)	Increase in women's knowledge of vitamin A, intake of vitamin A-rich vegetables (children), and purchase and consumption of liver, a food targeted by the intervention to increase vitamin A (by women and children)
Peru ^R Carrasco Sanes et al. 1998	Nutrition education in community kitchen with capacity building	Pre-post members/non-members	Reduction in prevalence of anemia	Increased quality of diet and intake of iron-rich foods as well as vitamin A, heme iron, and proportion of absorbable iron
Philippines ^B Brun et al. 1991 Solon et al. 1979 Popkin et al. 1980	Promotion of production of vitamin A-rich fruits and vegetables, with provision of seeds and seedlings and advice on agricultural practices	Paired pre-post	Improved weight-for-height and decrease in severe wasting. No change in serum retinol or clinical eye signs of severe vitamin A deficiency, implied no change in vitamin A status	Increase in children's vitamin A intake
Philippines ^B Solon et al. 1996	Promotion of homestead gardens with some target vegetables; provision of seeds and cuttings; mass media campaigns; social marketing, and nutrition education.	Pre-post, with control	No data collected on nutrition indicators (only dietary indicators)	Increased production of 5 types of vegetables with increased vegetable consumption and vitamin A intake in intervention group. Decrease in vitamin A intake in control group by 48%.

(continued)

Table 3 Summary of the Evaluation Findings of Horticultural and Nutrition Projects, Cont.

Country and References	Type of intervention	Design	Nutrition impact assessed	Other impact assessed
Senegal ^B Brun et al. 1989	Promotion of homestead gardens and sale of produce; nutrition education and agriculture education	Survey of those with & without homestead gardens (baseline; 10–12 years later)	No data collected on nutrition indicators (only dietary indicators)	Consumption increased for some nutrients, decreased for others.
*Tanzania ^{R,B} Kidala et al. 2000	Promotion of home production, consumption and storage of vitamin A-rich foods; health and nutrition education	Treatment/control Post	Lower serum vitamin A and higher helminths in treatment area. (Overall, higher intake of vitamin A-rich foods associated with higher serum vitamin A.)	Higher percentage of households with homestead gardens and producing vitamin A-rich vegetables in treatment area. Better knowledge, attitudes, practices about vitamin A, higher % using solar driers for vitamin A foods, higher 7-day frequency of intake of vitamin A foods.
Tanzania ^R Mulokozi et al. 2000	Promotion of solar driers; nutrition and health education.	Pre-post, with control	No data collected on nutrition indicators (only dietary indicators)	8% of women adopted solar driers in intervention area. No significant increase in % selling or in income from selling dried vegetables. Vitamin A food frequency score higher in treatment group and among adopters with increased intake of animal products.
Thailand ^{R,B} Smitasiri and Dhanamitta 1999 Smitasiri et al. 1999 Attig et al. 1993	Seed distribution; training of women farmers; promotion of gardens, fishponds, and raising chickens; nutrition education and social marketing	Pre-post, with control	Increased serum retinol, decreased vitamin A deficiency (in schoolgirls). Increased mean hemoglobin, decreased anemia, and low serum ferritin (not significant) implies improved iron status.	Increased knowledge, attitudes, and practices on vitamin A and iron; increased vitamin A intake; no change in fat intake; increase in iron intake in some targeted groups; increase in vitamin C intake in lactating women. No change in controls.
*Vietnam ^R English et al. 1997 English and Badcock 1998	Homestead gardens, fishponds, animal husbandry, nutrition education	Treatment/control Post	Data collected only on dietary indicators	Treatment group: lower severity and incidence of respiratory infections; better growth; greater fruit and vegetable intake; greater energy, protein, and vitamin A and C intake in children. Better knowledge, attitudes, and practices in mothers.
Vietnam ^B Ngu et al. 1995	Promotion of homestead gardens with a focus on vitamin A-rich crops, nutrition education for mothers	Pre-post	Clinical eye signs of severe vitamin A deficiency decreased to almost zero, implying improved vitamin A status.	Per capita vegetable production increased fivefold and increase in intake of energy, protein, and fat.

Source: Authors.

Note: Reviewed by Ruel 2001 and Berti et al. 2004. * = case study intervention; R = Ruel review; B = Berti review; abbreviations: NA = not available; HH = household.

tritional status of populations—but that homestead gardening alone is much less likely to improve nutrition. The review also emphasizes that using a gender-sensitive approach to agricultural interventions could strengthen their impact on nutrition.

The review published by Berti and colleagues in 2004 used a sustainable livelihoods framework to assess whether different agricultural interventions invest in different types of capital: human, physical, social, environmental, and financial. Interventions that invest more broadly in various types of capital, as is usually the case with homestead gardening programs, tended to have a greater impact on nutrition than those that focus more narrowly on agriculture. The authors concluded that the agricultural interventions most likely to be successful invest in natural, physical, social (including gender considerations), human (especially nutrition education), and financial capital.

The 2001 and 2004 reviews led to a common conclusion that homestead gardening projects after the mid-1990s were successful if they incorporated human capital–related components, notably communication and nutrition education activities targeting behavior change among their audiences, and the incorporation of gender considerations in project design. The power of nutrition education has been identified in other studies. Block (2003), for example, demonstrated that nutrition knowledge is a key determinant in how household food budgets are allocated. Households with nutrition knowledge allocate substantially larger shares of their household food budgets to foods rich in micronutrients and are unwilling to reduce consumption when staple food prices increase. This impact is not due to maternal schooling per se, which has been independently demonstrated to improve child nutrition outcomes.

Interventions involving animal source foods. Leroy and Frongillo (forthcoming) reviewed 15 intervention studies on animal source foods, including 4 on aquaculture, 5 on dairy production, 3 on poultry, and 3 in which livestock production was one component of larger integrated projects. The findings concerning the impacts of these studies on production, income and expenditure, women's status, and dietary intake and nutritional status are summarized in table 4, together with additional studies reviewed for this report. The studies cover several of the pathways outlined in chapter 2, including increased production of own consumption and in-

creased income, including increased income among women agriculturists. Most of the studies showed a positive impact on production of animal source foods, despite the large variability of promotional interventions. Similarly, most interventions that measured income or expenditures also reported increases in these indicators.

However, impacts on dietary intake and nutritional status showed mixed results. For aquaculture interventions, one intervention may have actually decreased dietary quality because it led to a switch from consumption of small fish (which are consumed whole and contain high levels of calcium and vitamin A) to greater consumption of larger fish with poorer micronutrient density (Roos et al. 2003; Bouis et al. 1998). In another, there were no differences in total fish consumption between the fish-producing and non-fish-producing households (Roos et al. 2003). In a third study, intervention households appeared to have consumed more fish, but the analyses were not subject to statistical testing (Thompson et al. 2000).

Similarly mixed results were found for dairy interventions. In one intervention in India, households in villages with milk cooperatives actually consumed less milk than households in villages without cooperatives. The overall nutrient consumption of households with cows in intervention villages did, however, rise, whereas nutrient consumption among nonproducing households fell (Alderman 1987). In another intervention in India, children in households that produced more than 5 liters of milk per day had adequate dietary protein intake, although none of the groups met their energy requirements (Begum 1994). A third intervention in East Africa found that households with crossbred cows consumed more energy, fat, protein, retinol, and iron than nonadopters, and in Kenya, women participating in the intervention reported increased milk consumption (Ahmed et al. 2000; Mullins et al. 1996).

Poultry interventions in Bangladesh and Egypt saw higher intakes of a range of nutrients among participating households than among nonparticipating households (Galal et al. 1987; Nielsen 1996). Another poultry intervention in Bangladesh did not lead to increased egg or chicken consumption, but participating households did eat more fish, suggesting that the intervention led to increased income and subsequent dietary change (Nielsen et al. 2003).

Table 4 Summary of Intervention Studies on Impacts of Animal Source Food Interventions on Nutrition-Related Outcomes

Country and References	Intervention	Design <i>Concern with Methods</i>	Production	Dietary intake and nutritional status	Income and expenditure	Women's status
AQUACULTURE						
Bangladesh Bouis et al. 1998	Polyculture fish production in household-owned or group-managed ponds (or vegetable production) to improve income; some nutrition education was provided, but primary objective was not better nutrition	Three groups: a. Adopters b. Potential adopters (in nonintervention villages) c. Random selection households not in a. or b. <i>Nonrandom assignment of households to groups</i>	n.a.	No effect on fish consumption; shift to larger fish, i.e., effect on nutritional status may be negative Modest effect through increase in income Preschoolers are favored, particularly boys Program effect on nutritional status not estimated	Positive but very modest increase in income	Demands on time relatively small
Bangladesh Roos et al. 2003	Poor farmers trained in carp culture. Household ponds were stocked with carp and either <i>mola</i> (species very rich in vitamin A) or other small indigenous fish species (SIS)	Treatment/control—post Unclear selection of households <i>No randomization</i>	No difference in production between <i>mola</i> and SIS ponds	No difference in fish intake between producing and nonproducing HHs 47% of the <i>mola</i> was consumed in the household, covering 21% of the recommended vitamin A intake	n.a.	n.a.
Bangladesh Thompson et al. 2000	Aquaculture extension (pond aquaculture) Households were expected to adapt monoculture of tilapia or silver barb or polyculture of native and exotic carp species using farm resources.	Treatment/control 2 control groups: neighboring households in same village and others from other area. <i>No randomization, no statistical tests</i>	Both extension recipients and neighbors have higher yields than control farmers.	Intervention and neighboring households seemed to consume more fish.	Return on investments higher in extension households	n.a.

(continued)

Table 4 Summary of Intervention Studies on Impacts of Animal Source Food Interventions on Nutrition-Related Outcomes, Cont.

Country and References	Intervention	Design Concern with Methods	Production	Dietary intake and nutritional status	Income and expenditure	Women's status
DAIRY						
India Alderman 1987	Integrating rural households into a market economy by increasing the use of purchased inputs and increasing the marketed surplus Dairy cooperatives were set up in the villages.	Treatment/control; pre/post comparisons of households in villages with and without dairy cooperatives <i>No randomization</i>	Villages with cooperatives produced twice the amount of milk as control group (result of > no. of cross-bred cows).	Households in villages with cooperatives consumed less milk. The nutrient consumption of milk-producing households in intervention villages rose, and that of nonproducing households fell.	Income and expenditure increased.	n.a.
India Begum 1994	Dairy Development Project of the Indian government; formation of dairy cooperatives	Treatment/control—post 3 groups in treatment: large (LP) (>5 l/day), medium (MP) (2.5–5 l/day), and small producers (SP) (<2.5 l/day) <i>No randomization, no statistical testing, no control for confounders, no details on intervention</i>	n.a.	Only children in the LP meet protein RDA. LP children have the highest energy intake also (do not meet RDA). Overall, protein and energy requirements best met in LP and worst in MP.	n.a.	n.a.
Ethiopia Ahmed et al. 2000 Tangka et al. 1999	Market-oriented dairying for smallholder mixed-crop and livestock farmers; use of crossbred dairy cows for milk production and traction; farmers with crossbred cows encouraged to grow fodder and received training on improved hygiene and restricted grazing; also veterinary and breeding services.	Treatment/control—post <i>Poor design, no baseline, no control for self-selection bias, no randomization, methodology poorly described, no control for confounders</i>	n.a.	Energy intake 19% higher in participating households Intake of fat, protein, retinol, and iron also higher (Ahmed, Jabbar, and Ehui 2000)	Income of treatment households higher Higher income associated with higher food and nonfood expenditure (Ahmed, Jabbar, and Ehui, 2000)	No apparent increase in women's labor input Men's incomes benefited significantly more from intensified dairying than women's (Tangka, Ouma, and Staal, 1999)

(continued)

Table 4 Summary of Intervention Studies on Impacts of Animal Source Food Interventions on Nutrition-Related Outcomes, Cont.

Country and References	Intervention	Design Concern with Methods	Production	Dietary intake and nutritional status	Income and expenditure	Women's status
DAIRY, CONT.						
Kenya	National Dairy Development Project: intensive dairy technology through introduction of crossbred cows, fodder production	Before (recall)/after No control for self-selection bias; no randomization; baseline data collected by recall; small sample size	n.a.	Increased milk consumption	Increase in HH income Increases in food purchases, school fee payments, and book purchases	Higher workload for women Increase in maternal income
POULTRY						
Egypt	More and Better Food Project	Treatment/control (adopters compared with nonadopters)	Increase in poultry production (and in maize, peanut, and wheat production)	Iron, total protein, and animal protein intake higher in adopting households	n.a.	n.a.
Galal et al. 1987)	Combined activities promoting plant production with animal production (poultry). 47% of poultry farmers were women.	No control for self-selection bias; no randomization; no clear use of statistics		Prevalence of iron-deficiency anemia dropped in school-age children during the same time period.		
Bangladesh	Participatory Livestock Development Project supporting semiscavenging poultry production; loans and technical assistance provided through women's groups	Treatment/control—post Unclear selection of households, no randomization, small sample size	Egg production significantly higher in adopting households No difference in chicken production	Egg and chicken consumption not different Women and girls in adopting households ate more fish.	Egg and chicken sales significantly higher in adopting households	n.a.
Nielsen et al. 2003						
Bangladesh	Saving schemes, technical training for poultry rearing and credit programs; project beneficiaries all women	Before/after Unclear methodology	Chicken production increased	HH consumption of eggs, chicken, fish, meat, and milk increased. Frequency of vegetable consumption did not change. Grain consumption increased.	All reported improved economic conditions. Both food and nonfood expenditure increased. % income spent on food decreased.	Women have gained influence in deciding on the use of income
Nielsen 1996						

(continued)

Table 4 Summary of Intervention Studies on Impacts of Animal Source Food Interventions on Nutrition-Related Outcomes, Cont.

Country and References	Intervention	Design <i>Concern with Methods</i>	Production	Dietary intake and nutritional status	Income and expenditure	Women's status
MIX OF INTERVENTIONS						
Ethiopia	Women-focused goat development project without impact on nutrition was expanded to include interventions to promote vitamin A intake, including nutrition and health education, training in gardening and food preparation, distribution of vegetable seeds, and school garden clubs.	Treatment/control Two treatment groups: local goats or cross-bred goats No control for self-selection bias	All of the newly started vegetable gardens during intervention period in participating households Participation significantly associated with vegetable garden ownership No other data on production	Goat owning households consume all produced milk. 87% by adults as hoja; children in participating households had slightly more diversified diet; more likely to consume milk more than four times a week Participating households consumed egg yolk at low rate (.46/wk) but significantly more than controls (.29) No impact on child anthropometry; clinical vitamin A deficiency lower in intervention children	n.a.	n.a.
Ayalew et al. 1999b						
Habtemariam et al. 2003						
Vietnam	Fishponds, livestock, home gardens, and nutrition education	Treatment/control <i>Only 1 intervention and 1 control, village no randomization</i>	Larger production of fish, eggs, vegetables, and fruits in treatment community	Children in treatment group had greater intake of vegetables, fruits, energy, protein, vitamin A, and iron and better child growth		n.a.
English et al. 1997						
Thailand	Promotion of poultry and rabbit raising and home gardens through a community-based intervention; school-based nutrition program	Before/after Treatment/control	n.a.	Increased intake of vitamin A in both intervention and control groups, but greater in intervention group	n.a.	
Smitasiri and Dhanamitta 1999						

(continued)

Table 4 Summary of Intervention Studies on Impacts of Animal Source Food Interventions on Nutrition-Related Outcomes, Cont.

Country and References	Intervention	Design <i>Concern with Methods</i>	Production	Dietary intake and nutritional status	Income and expenditure	Women's status
MIX OF INTERVENTIONS, CONT.						
	targeted to 10- to 13-year-old schoolgirls; girls received weekly iron supplement of 60 mg ferrous sulfate; improved school lunches; poultry raising, fishponds			Inconsistent findings for iron intake No increases in fat intake Schoolgirls had improved serum retinol and serum ferritin.		
Bangladesh, Nepal, Cambodia HKI 2003, 2004, 2004a 2006	Integration of animal components into existing gardening activities: poultry and eggs in all countries, milk and fish in Bangladesh Nutrition education targeted to women, nutrition improvement targeted at preschool children	Before/after, including quarterly monitoring data—Cambodia, Nepal Bangladesh, before and after, includes control group, quarterly monitoring data	Cambodia, Bangladesh—median number of eggs produced increased	Household chicken liver consumption increased Proportion of liver from own production increased (Nepal, Cambodia) Increase in egg consumption (Bangladesh, Cambodia). Children in project area consume double the number of eggs per week compared with rural Bangladesh.	In Bangladesh, Cambodia, and Nepal: 30%–66% of income from selling poultry used to purchase food. Additional food purchased in Cambodia 55% fish, 8% beef/pork In Bangladesh additional income used to purchase milk, fruit, and fish.	Program in chargs of Bangladesh targeted toward women. End line data show that women's engagement in decision making on household expenditures is greater.

Source: Adapted from Leroy et al. 2007, including notes to table. Additional material in table for HKI interventions in Bangladesh, Nepal, and Cambodia.

Three of the interventions focusing on animal source foods incorporated nutrition education and were combined with fruit and vegetable production (see “mixed interventions” in table 4). In Ethiopia, children in participating households had slightly more diverse diets and were significantly more likely to drink milk four or more times a week (Ayalew et al. 1999a; Habtemariam et al. 2003). In Vietnam the intervention group had higher intakes of vegetables, fruits, energy, protein, vitamin A, and iron and exhibited higher growth rates among children (English et al. 1997). It is not clear whether the animal production caused the positive effects because the interventions were multifactorial. In Thailand, vitamin A intake increased in the intervention and the control groups, but the increase was greater in the intervention group (Smitasiri and Dhanamitta 1999).

Leroy and Frongillo (forthcoming) concluded that the interventions associated with marked improvement in dietary intake and nutritional status had one of two key characteristics: either women played a critical role in the intervention or the interventions included a nutrition education component. The conclusion was consistent with those of earlier reviews, such as Ruel (2001). The only well-conducted study to contradict these conclusions was a study on the dairy cooperatives in India during the 1980s (Alderman 1987).

The authors note that an important question only partially answered in the reviewed studies was whether the reported increases in consumption were a direct effect of increased production or an indirect effect of increased income. For example, Alderman (1987) found that the increased nutrient consumption of milk-producing households was not due to an increase in milk consumption, and so was likely to have come through the income pathway.

GENDER OUTCOMES OF AGRICULTURAL INTERVENTIONS

The role of women farmers has received much attention in the past few decades. In 1995 the UN Food and Agriculture Organization estimated that women provide more than half the labor required for food production in the developing world and that this proportion is even higher in Africa. This is important from a nutritional perspective because

women’s status and their control over income are critical to improved nutrition outcomes.

Yet women farmers face a series of constraints that limit their potential as agricultural producers and their control of the resources that flow from the adoption of new technologies. The constraints are well-documented and include weak land rights, limited access to common property resources, lack of equipment and appropriate technology, limited contact with agricultural extension, lack of access to credit, and lower levels of education (Quisumbing et al. 1995). All of these constraints conspire to substantially lower the productivity of women farmers, resulting in high opportunity costs for households and communities (Alderman et al. 1995; Quisumbing et al. 1998).

Efforts to ensure that women benefit from agricultural development interventions can be broadly classified into three types of approaches: “women-only” projects, projects targeted to both women and men but with some resources allocated specifically for women, and projects in which gender issues are fully “mainstreamed.” A review of the evidence by Pena et al. (1996) found that the third approach is the most likely to improve women’s status in a sustainable way.

Interventions that seek to increase women’s access to or ownership and control of resources are generally quite complex. Failure to understand cultural norms and the gender dynamics within the household can result in unanticipated outcomes. In the Gambia, for example, a project geared to increasing women’s rice production was so successful that the land it was grown on was reclassified internally within the household. This resulted in output from that land being sold by men as opposed to women. Women therefore lost their original income stream, but did retain an increased labor commitment (Dey 1981). Vegetables and legumes are often regarded as women’s crops. Recognizing this, a project in Togo was successful because it promoted the introduction of soybeans as a legume rather than as a cash crop. Promotion as a cash crop would have resulted in the crop switching to male control.

The review in preparation by Leroy and Frongillo (forthcoming) of interventions promoting the production of animal source foods also assessed their impact on maternal income or women’s control over income. The results were quite mixed. For example, an intervention involv-

ing intensified dairy farming in Kenya showed that an important share of the additional income was controlled by women, whereas in Ethiopia men's incomes benefited significantly more from intensified dairying than did women's (Mullins et al. 1996; Tangka et al. 1999). Overall, the review found that whether women's income is likely to increase depends on the livestock or aquaculture production system, the nature of the intervention, and cultural beliefs and practices relating to gender. Even if the intervention is targeted to women's livestock and aquaculture activities, women may lose control over the income generated by those activities.

The authors also noted that women's livestock ownership rights may not be as stable as men's. In general, stress and constraints lead to an erosion of women's ownership rights because women's ownership of livestock is often considered a "secondary right." Evidence from around the world shows that the rights of pastoral women and their control over livestock management and marketing are being eroded (Niamir-Fuller 1994).

The authors concluded that women's control over income from livestock production activities is very site- and production system-specific. Livestock provides a real opportunity for women to increase their income in some situations. In other situations, however, it merely leads to a significant increase in women's workload without a considerable effect on their control over the additional resources. This conclusion is most likely also applicable to other types of food production systems.

LESSONS LEARNED

During the past 30 years development researchers and practitioners have generated substantial new information and insights into the best strategies for ensuring that agricultural interventions reach the poor, improve welfare, and have a positive impact on nutrition outcomes. Production is clearly an essential component of these interventions. The nature of the intervention will determine the effect on macro- or micronutrient supply: staple crops, for instance, can increase energy, whereas animal source foods can increase protein and micronutrients such as iron and vitamin A. But the special challenge of integrated agricultural-nutrition interventions is to translate

increased production into increased household consumption and individual intakes.

Overall, the review documented a wide range of agricultural interventions that have contributed to improved nutrition outcomes. In most cases, however, the exact pathways by which impacts on nutrition have been achieved are difficult to track. The reason is that studies document impacts on several intermediary outcomes such as food security, income, or women's empowerment, but without directly modeling these pathways of impact to nutrition outcomes. Because these outcomes are so closely intertwined, it is impossible to determine from this literature the relative importance of the different pathways linking agriculture and nutrition.

It is also clear that agricultural interventions have not always been successful in improving nutrition outcomes. For instance, although all the animal source food interventions reviewed were successful in increasing production of animal source foods, many failed to improve nutrition outcomes. That is because production alone is insufficient to bring about improved nutrition if it does not simultaneously address—or is complemented by other interventions that address—other determinants of nutrition such as improved healthcare. Agricultural interventions thus cannot be expected to achieve impacts on nutrition outcomes unless they are integrated with complementary efforts to address other issues such as high levels of morbidity and inappropriate child-feeding practices.

The review of evidence presented above suggests a number of general lessons about how agricultural interventions can be designed to achieve nutrition-related objectives. Most of these lessons pertain to processes and general approaches rather than packages of specific components and should be considered by planners when devising more strategic approaches to nutritional goals:

Follow an integrative process of planning and implementation. Successful interventions usually incorporate both agricultural and nutrition considerations at all phases of planning. Intervention activities should be integrated with other health and development services and should work in partnership with different actors in the field.

Take local agricultural and nutrition contexts into account, and seek opportunities to build relationships with local partners that are intimately familiar with these contexts. Successful interventions

often work with local groups and organizations—often nongovernmental organizations—that are well placed to engage and consult with farmers as participants in designing interventions and developing or adapting technologies. These local counterparts can be especially valuable in identifying opportunities to relate the intervention with existing programs and to integrate intervention components into those programs. These opportunities can be important, and capitalizing on them can yield positive effects on the intervention's sustainability. Successful gardening interventions are an excellent example. Those which have carefully considered traditional gardening practices and the goals and preferences behind gardeners' production decisions have a distinct advantage. Highly relevant, adaptive, and sustainable changes can be introduced by identifying and making available improvements that satisfy the gardeners, using the gardeners' own criteria and accounting for and accommodating the gardeners' own priorities, incentives, vulnerabilities, assets, constraints, and livelihood strategies. This requires a trusting, collaborative relationship between the researcher or project personnel and the participating community—a relationship in which the project personnel are necessarily attentive and sensitive listeners and in which the community knows that its concerns have been addressed. Local engagement is also important in ensuring that the scope and causes of nutrition problems among targeted groups are accurately identified. The importance of local engagement suggests that a suitable approach includes investing in pilot studies before large-scale programs are initiated and then incorporating what is learned about the existing conditions, climate, and local culture.

Mainstream gender. Women play multiple roles in both agricultural production and nutrition, and interventions that consider trade-offs between their respective roles and their time and labor constraints are more likely to lead to positive outcomes. Successful interventions are more likely to take into account the range of factors that differentially enable or constrain men and women in terms of access to resources like land and services like credit. These influence and often determine their roles as decision makers in the household or community. The significance of gender equity is particularly critical because women's status and

decision-making power directly affect the nutritional status of their children.

Incorporate communication and education components that target behavior change. Interventions that successfully translate increased production into better nutrition outcomes, especially for children, usually incorporate communication strategies that relate the significance of positive or negative behaviors to health and nutrition effects. Information is a vital resource, and households that are equipped with an understanding of nutrition- and health-related information display a tendency toward more favorable allocation of food and health budgets. Raising awareness of the health benefits of a newly available food commodity, one for instance that addresses a prevalent local micronutrient deficiency, may be an important factor in its adoption among producers, including those growing food for their own households' consumption. The importance of educational components is perhaps most pronounced among mothers, whose roles as caregivers extend to other, nonfood determinants of nutrition, such as hygiene and sanitation practices and preventive and curative health. Armed with sufficient information, they are moreover more likely to know when it is necessary to avail household members of health services.

Monitor and evaluate progress. Interventions with sustainable impacts are generally characterized by effective monitoring and feedback loops that enable responsiveness to the shifting realities participants face. The nutrition-related objectives pursued by the agricultural intervention will most likely remain unchanged, but the factors that act upon that objective may very well be in flux. Changing livelihood strategies may be a particularly important set of developments to track, and here too, monitoring is likely to benefit considerably from good rapport between project personnel and participants.

Taken together, these lessons show that agricultural interventions are most likely to have an impact on nutrition outcomes when they involve diverse and complementary processes and strategies that redirect the focus beyond agriculture for food production and toward broader consideration of livelihoods and optimal intrahousehold use of resources. Successful projects are those that invest broadly in improving human capital and that sustain and increase the livelihood assets of the poor.

The four case studies of agricultural interventions presented in this chapter, none of which were included in previous reviews, provide insights into new approaches to the agriculture-nutrition nexus. All four interventions, explicitly aimed at integrating agriculture and nutrition during planning and implementation, took into account lessons learned in previous interventions and documented quantitative diet or nutrition outcomes at the individual level.

ORANGE-FLESHED SWEET POTATO PRODUCTION AND VITAMIN A DEFICIENCY IN MOZAMBIQUE

Background. The first case study provides new insights into the use of a new technology, biofortification, as a nutrition-focused agricultural intervention. Staple foods interventions are generally not viewed as direct routes toward improving nutrition outcomes. This is particularly true in the case of primary staples like rice, maize, wheat, and cassava, which are good sources of energy but not of bioavailable micronutrients. Biofortification, the process of breeding food crops that are rich in bioavailable micronutrients, is attempting to overcome that limitation. One biofortified staple crop—orange-fleshed sweet potato (OFSP)—is already being widely disseminated, particularly in Sub-Saharan Africa. Unlike most staple crops, even unimproved OFSP is rich in vitamin A, and efforts to biofortify OFSP have included selection and breeding for still higher concentrations of the vitamin A precursors known as carotenoids.

OFSP has been selected as a focus crop in a number of efforts to improve vitamin A intakes, including the Vitamin A for Africa (VITAA) partnership and the HarvestPlus biofortification program. OFSP is promising for a number of reasons. It contains very high levels of carotenoids; it is well accepted by the young children who are usually targeted; and it is easy to cultivate, is vegetatively propagated, and is fairly drought-resistant once established. It is also a good source of energy for children and adults. Together these qualities make OFSP an excellent food security crop. It is also less labor-intensive than most other staple crops, and this is particularly helpful to labor-constrained households, such as those affected by HIV/AIDS. It can be planted over a broad range of time without considerable yield loss and can fill

Box 2 Introducing Orange-Fleshed Sweet Potato in Rural Mozambique

Context

A two-year intervention research project in drought-prone areas of Zambézia Province in Central Mozambique. The area is characterized by high levels of young child malnutrition, a monotonous diet with cassava as the primary staple, and a very poor resource base. Vitamin A deficiency is highly prevalent in rural Mozambique and in the study area (58 percent at baseline). White-fleshed varieties of sweet potato (WFSP) were already widely cultivated and consumed in the area.

Program model

The following three related elements—each necessary and none sufficient alone—were addressed to increase intakes and improve child serum retinol:

- Increase farmers' access to improved orange-fleshed sweet potato (OFSP) vines and roots.
- Increase nutrition knowledge and create demand for OFSP.
- Ensure sustainability through market development.

Interventions:

- Farmers received free OFSP vines via farmers' associations (as per government extension practice at the time).
- Demand was stimulated through multiple communication channels: community theatre and

radio spots and visible presence at local markets, as well as nutrition extension.

- Integrated agricultural and nutrition extension services reached 718 women farmers and 323 men. Extension supported production, storage, processing, commercialization, and marketing to create demand.
- Nutrition extension aimed to improve infant and young child feeding practices using OFSP as one input.
- A grading/pricing scheme was developed in partnership with a trader, rewarding quality.
- Several processed products were developed and marketed ("golden bread" and OFSP juice).

Year 2 results and impact:

- Ninety percent of intervention households produced OFSP (vs. 11 percent controls); of these 30 percent sold OFSP.
- Mean sweet potato plot size increased more than 10-fold in intervention households.
- Agronomic performance was acceptable, with yields similar to WFSP.
- OFSP was the cheapest source of vitamin A (per retinol unit) in local markets.
- Intervention children were 10 times more likely to eat OFSP frequently.
- Vitamin A intakes among intervention children were 8 times higher than controls; energy in-

continued

some seasonal gaps in energy and vitamin A intakes. Finally, prices are generally low enough that families will choose to keep some OFSP for home consumption, rather than selling all they produce.

This case study reports on the results of the "Toward Sustainable Nutrition Improvement Project" in Mozambique (Low et al. 2007a; Low et al. 2007b; Low et al. 2005). The project is purposefully built on lessons learned from an earlier OFSP intervention project in Kenya (Hagenimana et al. 2001).³ Box 2 presents a summary of the program characteristics and set of interventions and lessons learned.

Assessing impact. Evaluation design and data collection. The evaluation employed a prospective, quasi-experimental design. The objective was to measure the impact of the intervention on children's vitamin A status (using serum retinol) and to document changes in the intermediate factors leading to the nutritional impact, that is, changes in knowledge, OFSP production and consumption, and vitamin A intake. Three districts were purposefully selected. Within districts, villages were

3. Project website: <http://aec.msu.edu/fs2/tsni/index.htm>.

Box 2 Introducing Orange-Fleshed Sweet Potato in Rural Mozambique, Cont.

takes and intakes of several other micronutrients were also higher.

- Prevalence of low serum retinol among young children decreased from 60 percent to 38 percent (no change in control communities).

Lessons learned and questions for the future:

- Free vines meant farmers had limited incentive to preserve vines for planting next season; sustainability depends on ability and willingness of farmers to invest in improved vine conservation and multiplication or a willingness to pay for vines.
- The extension package was relatively intensive; more operational research is needed to identify the lowest cost and most cost-effective package of interventions that can achieve public health impacts.
- Further research is needed to determine whether adoption of OFSP is sustained without continual input on demand creation side.

Sources: Towards Sustainable Nutrition Improvement webpage: <http://www.aec.msu.edu/fs2/tsni/index.htm>, accessed February 27, 2007; Low et al. 2007b; Low et al. 2007a.

Project partners included Michigan State University; the Nutrition Division of the Ministry of Health, Mozambique; World Vision Mozambique; the National Institute for Agronomic Investigation (Mozambique); the Southern African Root Crops Research; and Helen Keller International. The project was funded by the Micronutrient Initiative, the Rockefeller Foundation, the United States Agency for International Development, and HarvestPlus.

stratified by distance to services and other characteristics and randomly selected within strata. Within villages, all households with age-eligible children were invited to participate; in intervention areas, study participation also entailed participation in local farmers' groups. A series of nine surveys were undertaken. Information was gathered on socioeconomic and demographic characteristics of households, agricultural production, child morbidity, adult and child anthropometry, parental nutrition knowledge, food frequency, dietary intakes, and biochemical indicators. In addition, sweet potato plots were measured annually, and market prices were monitored monthly.

Impact results. The evaluation showed a marked decrease in vitamin A deficiency among intervention households, from 60 to percent 38 percent. That was accompanied by significant changes in several of the intermediary factors along the impact pathway, that is, large increases in production of OFSP as well as positive changes in knowledge about vitamin A and child intake of vitamin A.

Strengths and limitations of the evaluation. The primary strengths of the evaluation component lay in the prospective design and in the comprehensive series of surveys, which documented a wide range of intermediate as well as final outcomes. The main

design limitation was that participation in intervention areas was restricted to those willing to join farmers' groups, which precluded a full exploration of determinants of adoption. This also raised the possibility of a self-selection bias, but this threat to internal validity was addressed in the analysis. In addition, the time frame did not allow an assessment of sustainability. Finally, this pilot project was relatively small. Nevertheless, the study results provide "proof of concept" and support the relevance and the potential for impact of the larger VITAA, biofortification, and other efforts.

Innovations. The project took several steps to ensure effective implementation and to maximize the potential for impact of this innovative agriculture and nutrition intervention. Key features of the project planning and implementation, which are believed to have contributed to its success, include the following:

- Integrated agriculture and nutrition components at every stage of planning and implementation;
- Established links between researchers and communities through implementing partners;
- Identified and selected nutrient-dense varieties that *also* addressed the needs of farmers and the preferences of consumers;

- Were grounded in thorough knowledge of context;
- Gave due consideration to the roles of women and the constraints they face as farmers;
- Included strong nutrition education and demand creation components, using multiple channels and targeting multiple audiences;
- Addressed sustainability through efforts to develop local markets for OFSP;
- Employed quasi-experimental evaluation design and gathered detailed data on intermediate outcomes to enhance assessment of impact.

LEGUME SYSTEMS AND CHILD NUTRITION IN MALAWI

Background. The second case study highlights the potential for a crop often overlooked as a nutrition-focused intervention: legumes. Legumes do not provide extremely high quantities of any individual micronutrient. But they are good sources of a range of macro- and micronutrients, and they substantially improve the quality of grain/root/tuber-based diets, for both young children and other family members. The incorporation of legume plant residues can improve soil fertility and potentially increase future harvests. For these reasons, interventions involving legume systems are being implemented by a variety of organizations.⁴ Within the health sector, a number of nutrition education interventions have aimed to increase young child intake of legumes. Yet there are very few documented examples of agricultural interventions that focused on legumes and that also recorded impacts on individual diets or nutrition outcomes. One such study is the Soils, Food, and Health Communities Study (SFHC) in northern Malawi's Soils Food and Health Communities Project (Kerr and Chirwa 2004).⁵ The SFHC study explored whether a legume system intervention could improve soil fertility, food security, and child nutrition (Kerr 2006; Kerr and Chirwa 2004).

Assessing impact. Design and data collection. The SFHC project was designed as a participatory research project introducing legume systems and using an ecosystem framework to examine the systems' links with food security and health. Project documents identify "monitoring change" as an objective, and the wide range of research activities un-

dertaken were not necessarily designed to measure and attribute impacts. Nevertheless, some study elements incorporated a quasi-experimental approach, including the use of random sampling for quantitative surveys in intervention and comparable control villages over the life of the project. In total, 24 research activities were undertaken between 2000 and 2004, including focus group discussions, semistructured interviews, participatory mapping, indicator development, yield collection exercises, soil and biomass sampling, and quantitative surveys covering dietary intakes, anthropometry, and hemoglobin measurement. The qualitative exercises covered a range of topics, including child care and feeding, legume expansion, and the nature of crop residue use and seed exchanges.

Evaluation results. Box 3 summarizes the results of the study so far. One notable success is reflected by the expansion of farmer participation, which grew from 183 farmers in 7 villages in the first year to nearly 3,000 farmers in 77 villages in the fourth year. This included a relatively high participation by women (Bezner Kerr and Chirwa 2004). Preliminary results also indicate that the project succeeded in nearly tripling the frequency of legume consumption by young children, relative to controls (PATH Canada 2004). Further analyses of child nutrition outcomes, including anthropometric outcomes, are ongoing (P. Berti, personal communication).⁶

Strengths and limitations of the evaluation. Available documentation did not allow an assessment of the evaluation design and sampling. The evaluation's strengths lay in its use of rich qualitative information, which provided insights into the implementation, adoption, and demand for project activities.

Innovations. Like the OFSP intervention study, this project built on a range of lessons from the

4. See, for example, the Collaborative Crop Research Program at <http://mcknight.ccrp.cornell.edu/projects/index.html>. This program supports several legume systems projects in Africa (Tanzania, Malawi, and Mozambique) and Latin America (Bolivia and Ecuador) aimed at improving the use of legumes, improving child nutrition, or both.

5. Web site: http://www.healthbridge.ca/food_soil_e.cfm. Accessed February 27, 2007.

6. The project is also continuing in a second phase; see the HealthBridge (formerly PATH Canada) website at http://www.healthbridge.ca/food_soil_e.cfm for a project description.

Box 3 Legume Systems in Malawi: Building on Local Knowledge, Improving Nutrition

Context

A three-year participatory research project (intensive case study) in Mzimba District, northern Malawi. The area is characterized by high levels of young child malnutrition and a monotonous diet with maize as the primary staple. A variety of legumes are grown in the region. Soils are deficient in nitrogen, and input use is low.

Program model:

- Human health and nutrition can be enhanced through design of solutions based on ecosystem management.
- Farmer Research Teams (FRT) can be used to test and promote agricultural innovations.
- To achieve nutrition impacts, FRT embrace and emphasize links between legume production and child nutrition in all farmer meetings, trainings, and farm visits.

Legume systems tested:

- Maize intercropped with pigeon pea
- Pigeon pea intercropped with soybean, then rotated with maize
- Pigeon pea intercropped with groundnut, then rotated with maize
- *Mucuna pruriens* (velvet bean) rotated with maize
- *Tephrosia vogelii* intercropped with maize

Process/qualitative results:

- Participation increased rapidly from 183 farmers (year 1) to nearly 3,000 farmers (year 4).
- Participating farmers developed indicators and assessed legume systems with regard to effects on soil fertility, food security, child nutrition, and gender and other social issues.
- Farmers' motivation for adoption was to provide family food, not to enhance soil fertility or to sell.
- Choice of legume systems reflected their role in filling seasonal food gaps.
- Legume system "best" for soil fertility had many undesirable qualities (very long cooking time, need to bury residue during busy season) and was not adopted.
- FRT were overwhelmed in year 2, leading to development of village committees to support FRT.
- Majority of committee members were women, who cited link with child nutrition as their motive for joining.
- Men were reported to make decisions about crop use and sale, but, in fact, women retained some control over both.
- Discussions of gender role changes met with resistance from men and grandmothers, but a focus on child health served to "neutralize" conflicts.

Sources: Soils Food and Health Communities Project webpage: http://www.healthbridge.ca/food_soil_e.cfm accessed February 27, 2007; Kerr and Chirwa 2004; PATH Canada 2004.

Project partners included PATH Canada, the Ekwendeni Mission Hospital, and the Farmer Research Teams. The project was funded by the International Development Research Centre (Canada).

past. Agricultural and nutrition concerns were integrated from the outset. Gender issues and other social relations were carefully assessed and addressed, nutrition education was aimed at ensuring impacts on child diets, and a number of research elements did allow some monitoring and assessment of impacts. Strong participatory and qualitative approaches were employed throughout the life of the project. Farmer research teams, com-

prising farmers selected by community members, carried out research along with external team members. The methods used to select farmer research team members were designed to ensure representation of less-advantaged community members, thus addressing an important shortcoming experienced by several past efforts in which teams were dominated by men and better-off household members.

INTEGRATING HOMESTEAD GARDENING AND PRIMARY HEALTH CARE ACTIVITIES IN SOUTH AFRICA

Background. The third case study focuses on yellow fruits and vegetables, including dark green leafy vegetables in South Africa and is a useful example of an agricultural intervention that explicitly partnered with the health sector. The pilot study was implemented in 1999 in a rural village in Kwazulu-Natal, South Africa, to promote the production of these crops at the household level. The project effectively linked an agriculture intervention with a set of health-sector activities to stimulate greater consumption of the products. The intervention package included both an agriculture intervention and a health-nutrition intervention.

Agricultural intervention. The project provided a course on the theoretical and practical aspects of vegetable production, such as soil preparation, fertilizers, planting and sowing dates, plant spacing, irrigation, crop rotation, cultivar choice, weeding, maintenance, pest and disease management, and harvesting (Faber and Benade 2003). Homestead gardens were present prior to the intervention and included traditional garden crops such as cabbage, maize, vitamin A-rich pumpkin, and imifino (a collection of dark-green leaves). A total of nine demonstration gardens were established with the following crops: butternut squash, carrots, orange-fleshed sweet potatoes, and spinach, along with a papaya tree. These crops were new additions to the gardens but were already familiar to communities in the area through their availability for purchase in local markets (Faber et al. 2002a).

Health-nutrition intervention. In 1995 a community-based growth-monitoring program was established in partnership with the health sector. The program is a primary health care activity run by nutrition monitors through home-based centers known as Isizinda. The project was able to engage the Isizinda as a focal point to promote the local production and consumption of provitamin A-rich foods. They also served as agricultural demonstration and training centers and as nutrition education centers providing instruction on the relation between vitamin A and health, the identification of vitamin A-rich foods, and cooking methods.

Vegetables produced in the demonstration gardens were cooked at the Isizinda on days when child growth was monitored (Faber et al. 2002b).

Assessing impact: Evaluation design and data collection. Serum retinol concentrations of 165 children ages two–five were collected at baseline, and their food consumption was recorded during a cross-sectional survey covering the intervention village. A neighboring village served as a control village. One year after implementation, the mothers of a convenience sample of 100 two- to five-year-old children (50 from households with a project garden and 50 from households without a project garden) were interviewed. Data collected included food intake from 24-hour recalls. A cross-sectional survey was also organized 20 months after program implementation; serum retinol concentrations of 221 children (110 from the experimental village and 111 from the control village) were measured, along with information on dietary intake and growth of the children, and maternal knowledge on vitamin A.

Results of the one-year follow-up revealed that dietary vitamin A intake increased significantly in children from households with a project garden, and to a lesser extent in children from households without a project garden. Twenty months into implementation, results revealed that after the onset of the intervention, the number of project gardens gradually increased to reach a total of 126 gardens (including demonstration gardens). Only 8 percent of the households with project gardens sold some proportion of the produce for cash. Between baseline and the 20-month follow-up, there was a significant increase in maternal knowledge scores in the experimental village compared with the control village.

At the same time, significantly more children in the intervention village than in the control village consumed carrots, pumpkin or butternut squash, spinach, and imifino—all vitamin A-rich foods. From baseline to follow-up, serum retinol concentrations increased significantly in the experimental village and decreased significantly in the control village. At follow-up, children from the intervention village had higher serum retinol concentrations than children in the control village; the reverse was true at baseline. Among the children in the experimental village, those from households

without a project garden had significantly lower serum retinol concentrations than did those from households with a project garden, and their concentrations were similar to those of children from the control village. Because all households in the intervention village were exposed to the same nutritional education and agricultural demonstration sessions regardless of whether they had a project garden, the finding above suggests that access to supply was critically more important than was education without ready access.

Strengths and limitations of the evaluation. The home-gardening program had a positive effect on serum retinol concentrations, habitual intake of targeted garden crops, and maternal knowledge about nutrition. In addition, villagers appreciated the fact that they no longer had to buy vegetables and recognized the health benefits apparent among their children. The evaluation did, however, have several weaknesses. The treatment and control groups were not randomized, and the effect of the intervention was assessed using a cross-sectional survey comparing households with and without gardens. Self-selection of households (i.e., participating or not in the garden project) was not controlled for, and for logistical reasons, the evaluation survey was done at the beginning of the new growing season for many crops (20 months), when mostly spinach and carrots are available. Had the evaluation been conducted at 24 months, then orange-fleshed sweet potatoes and butternut squash would have been in abundance. It is likely that the effects on consumption and nutritional status would have been even larger.

Innovative features and success factors. The success of this project appears to be attributable, at least in part, to successful coordination among multidisciplinary groups of agriculturists, nutritionists, and the community. The inclusion of complementary project components such as the primary health care activity (which monitored child growth) and nutrition education likewise also contributed to the project's success. Nutrition and agriculture education were found to be necessary but not sufficient conditions to achieving marked improvements in nutrition. This finding suggests that, at least in this context, food insecurity was a significant constraint to behavior change and that the collaboration between agriculture and health allowed the synergies between the two sectors to improve nutrition.

HOMESTEAD GARDENING FOR FRUITS, VEGETABLES, AND LIVESTOCK IN ASIA

Background. The fourth case study involved homestead gardening for fruits, vegetables, and livestock in Bangladesh and is notable not only for the range of commodities it dealt with, but also because it is a rare example of an intervention that was scaled up from the community to the national level and was ultimately replicated in other countries.

Homestead gardening in Bangladesh is a mainly seasonal activity, with about 70 percent of fruits and vegetables being produced in winter. Vegetable and fruit production satisfies less than 30 percent of national demand. In an attempt to gain a better understanding of existing gardening practices, Helen Keller International (HKI) conducted a small assessment in north-west Bangladesh in 1988. On the basis of the findings, HKI developed a pilot program among 1,000 households between 1990 and 1993. The aims of the program were to (1) explore the feasibility of promoting low-cost vegetable gardens combined with nutrition education and (2) identify constraints that might prevent increased production and consumption of vitamin A-rich foods among poor households.

The pilot program provided a wealth of information on the successes and challenges of gardening programs in Bangladesh and provided Helen Keller International with the information it needed to expand the program. Among the results were encouraging data suggesting that household production of fruits and vegetables could be possible throughout the year with some technical assistance and support. A midterm evaluation in 1992 confirmed that the combined homestead gardening, nutrition education, and gender aspects of the program had a very positive impact on vegetable consumption among women and young children. The monitoring and evaluation system of the pilot program also identified challenges that needed to be overcome. For instance, households were unable to sustain change without a regular supply of quality seeds and other inputs. Scaling up the pilot would require greater understanding of a number of issues, including cultural beliefs about child feeding, maternal food intake during pregnancy, intra-household food distribution, and the role women play in program activities.

The large quantity of data provided by the pilot program was then used to develop a larger-scale homestead gardening program, including the need for adequate management and human resources to implement a large-scale community program. The pilot study was expanded in collaboration with local NGOs and the government of Bangladesh into the “NGO Gardening and Nutrition Education Surveillance Project” in 1993 (Talukder et al. 2000). Eventually, the program was scaled up to national-level coverage, supporting 900,000 households supporting 4.5 million beneficiaries.

On the basis of the success of the experience in Bangladesh, the project was replicated by Helen Keller International in Cambodia, Nepal, and the Philippines and adapted to Niger (HKI 2004, 2006). Recognizing that micronutrients like vitamin A are less bioavailable from vegetable sources, HKI began a pilot extension of its home-gardening program by integrating animal husbandry in Cambodia, Bangladesh, and Nepal. The incorporation of an animal-source food intervention benefited richly from collaboration with a long-running, well-established program with capacity for nutrition education, production training, and monitoring and evaluation.

Intervention elements and scope. The objectives of the Bangladesh homestead gardening program were threefold:

- To increase the number of households that sustainably produce different varieties of vegetables and fruits throughout the year
- To increase the number of households producing more varieties of vegetables
- To increase consumption of vitamin A-rich foods and improve the nutritional status of the most vulnerable groups

The gardening and nutrition education activities were linked with the ongoing development programs of local NGOs. Strong linkages were established with participating communities to ensure sustainability. The NGOs’ work with women’s groups helped them to address the social and cultural constraints faced by women in Bangladesh. These NGOs were supported financially by HKI for the first three years of the project. The establishment of village-level nurseries and homestead gardens was conducted by the NGOs in conjunction with community groups. The village nurseries served as a community support service network in

which demonstrations and training on low-cost, low-risk gardening practices were conducted and seeds, seedlings, and saplings were produced and distributed. Most of the village nurseries in the program operated as small enterprises.

Each NGO was encouraged to form 45 village nurseries per subdistrict, with a minimum of 800 square meters serving 5 to 10 villages. Five to 10 working groups of the NGOs of approximately 20 women each were linked to each nursery to participate in the gardening program. A group leader or selected individual was identified to develop and manage the nursery. The group leader also facilitated nutrition and health education through peer education among the women’s groups. HKI provided training and technical assistance to the agriculturists and extension agents of the partner NGOs and, together with them, provided technical assistance based on the needs of the households and nursery owners. This technical assistance was designed to reinforce and improve existing positive gardening and consumption practices.

Program monitoring was an essential part of program implementation and was particularly important in scaling up. Monitoring was used to identify problems and priorities and develop solutions based on sharing between the beneficiaries and the program staff. In addition to the monitoring of program activities, HKI staff regularly supervised NGO field and management staff. By implementing the program in partnership with NGOs, households continue to receive technical support for homestead gardening and the program continues to expand without input and resources from HKI.

Gender was an important focus of project activities. Women in rural Bangladesh have traditionally managed seasonal homestead gardening, from sowing to harvesting and storing seeds. Thus the program actively targeted women in an effort to provide them with new opportunities to generate income related to homestead gardening. Women are also generally responsible for procuring and preparing food for their children. It is estimated that at least 90 percent of the targeted households are represented by women.

To incorporate animal source foods into the intervention, model farms were established with existing village nurseries. The animal source foods of focus were poultry in Cambodia and Nepal and poultry, milk, and fish in Bangladesh. Each model farm supported a number of households with

training and support for household poultry rearing, including improved breeding stock and chicken management services. Nutrition education focused on dietary diversity, micronutrient consumption, and maternal and child nutrition (HKI 2003). In Cambodia, the village-level poultry farms were owned by village farmers and run as microenterprises.

Assessing impact. The NGO Gardening and Nutrition Education Surveillance Project used an integrated monitoring system to provide regular feedback on program progress. The data were collected on a regular basis using a simple questionnaire on seed production, vegetable and fruit production and consumption, and income. In addition, a cross-sectional survey was conducted in February and March 2002 to evaluate the economic and social impact of the program on its beneficiaries and the sustainability of the program.

This evaluation comprised three groups of 720 households each, totaling 2,160 households, representing active program participants, former program participants, and control households. Structured questionnaires were used, and data on homestead garden production were estimated in kilograms by the homestead caretaker. Additional information was collected on the adoption of year-round production practices, consumption levels of garden produce, amounts of cash generated, changes in the ability of women to contribute to household livelihoods, and other developments.

Evaluation results. The program increased the production and consumption of fruits and vegetables in the areas it covered and increased the number of varieties consumed. Monitoring showed that the percentage of households without a homestead garden decreased from 25 percent at baseline to less than 2 percent after one year (Talukder et al. 2000). After one year of participation in the program, the percentage of households who practiced year-round (developed) gardening had increased significantly from 3 percent to 33 percent. The number of varieties and the volume of vegetables produced in developed gardens were three times higher than those produced using traditional gardens. The cross-sectional evaluation conducted in winter 2002 revealed that households participating in the project produced a median of 135 kg of vegetables and 24 kg of fruit in the preceding three months, compared with 46 kg of vegetables and 14

kg of fruits during the same period for control households (Bushamuka et al. 2005).

Results also revealed that children in households with developed gardens consumed 1.6 times more vegetables. Among children ages 12–59 months who had not received a vitamin A capsule in the six months prior to the survey, the risk of night blindness was lower when their house had a homestead garden. Thus, having a homestead garden appeared to reduce the need for vitamin A supplementation.

Seventy-three percent of the gardens were managed by women, and women were the main decision makers concerning gardening practices and the use of the income earned by selling garden produce (Talukder et al. 2000).

Households earned, on average, the equivalent of US\$8 on a bimonthly basis by selling the fruits and vegetables. The main use of this income was for food and also to invest in seeds, seedlings, saplings, poultry, or other income-generating activities. Nearly 10 percent of households saved income generated from the garden. Results also revealed that households with improved or developed homestead gardens consumed micronutrient-rich, noncereal foods more frequently than did other households. These foods, such as lentils and animal products, are not actually produced in the garden, but were purchased using income generated from the selling of garden produce (HKI 2003).

Chicken liver is a particularly rich source of vitamin A and other essential micronutrients. In Cambodia and Nepal, the percentage of households consuming chicken liver increased from 21 percent to 35 percent and from 28 percent to 41 percent, respectively, among those households consuming it from their own production.

In Bangladesh and Cambodia, egg production and consumption increased. In Bangladesh, 94 percent of the participant households consumed eggs in the seven days before the survey—an increase of 48 percentage points over the baseline. More important, egg consumption increased disproportionately among women and children, almost doubling. There were no changes in egg consumption in the control group. Nutrition education emphasized both intrahousehold distribution issues and micronutrient consumption and focused on the special needs of women and young children.

Strengths, limitations, and conclusions. This program is a success story of the scaling up of a small-scale gardening program. Limited experience exists of successful scaling up of gardening and nutrition programs, and the Bangladesh model is one that has been well documented and has been successfully replicated in several countries in Asia.

The program continues to expand in Bangladesh into new areas and to additional households in the current working areas. The gardening model has been adopted by the Government of the People's Republic of Bangladesh and has become part of a program of the Department of Agriculture Extension. In 1997, HKI started the phaseout of technical and financial support to NGOs that had already received three years of its support. Monitoring information from these areas one year after the withdrawal shows that the households are maintaining their improved gardening practices and continue to consume fruits and vegetables more regularly.

LESSONS FROM THE FOUR CASE STUDIES

The case studies drew from the experience of many previous interventions. All four employed a nutrition education component directed at behavior change in the participating communities. Each of them also took local contexts into account, built partnerships with different members of the communities to promote ownership, and purposefully involved women and targeted their empowerment.

All four interventions achieved their ultimate objective of improving the intake of focus nutrient-rich foods by target population groups, especially women and young children. The two studies that measured biochemical indicators of vitamin A deficiency also documented a significant reduction in the prevalence of vitamin A deficiency in children. The Bangladesh study documented reductions in night blindness (a clinical sign of vitamin A deficiency) among children of households with a homestead garden. Although none of the studies rigorously modeled the pathways of impact the interventions followed, the marked increases recorded in production, consumption, and intake suggest that the direct pathway of consumption of

own production was the dominant one. The income pathway was not as consistently documented, thereby preventing a firm conclusion about its relative importance across the four case studies. The Bangladesh-Africa study, however, does document an impact on income, which translated into purchasing and higher-quality foods and overall enhanced diet quality and nutrient intakes.

The case studies each made a unique contribution to the current understanding of potential modalities linking agriculture and nutrition and key success factors. The biofortified orange fleshed sweet potato intervention, which resulted in large increases in vitamin A intakes and status, provides encouraging signals for future interventions involving this newly bred crop. The focus on gender in the legume project was highly successful in achieving meaningful increases in legume consumption in young children. In South Africa, the successful partnership between the agricultural and health sectors appears to be responsible for the impacts on maternal knowledge and vitamin A status. That study also underlines the importance of boosting food availability and access through agriculture in contexts in which food insecurity is a major constraint to behavior change. In Bangladesh, both the production-consumption-intake pathway and the income pathway appeared to have played a role in improving vitamin A intake and status. The Bangladesh case study is also a unique example of the successful scaling up of a homestead garden project and of the importance of focusing on women.

Earlier reviews had noted the importance of properly designing and conducting evaluations of agriculture and nutrition interventions to better document impact and best practices. The case studies reaffirm that careful evaluation design is critical but remains a challenge because all the methodologies employed had certain limitations. Scaling up also remains a challenge. With rare exceptions, the interventions remain small in scale and unlikely to achieve broad impacts. To scale up agricultural interventions to have a broad and sustainable impact requires their integration into the activities of institutions, both in the agriculture sector and in other sectors whose activities can contribute to improved nutrition outcomes. These institutional issues are dealt with in chapter 6.

The Changing Context of Agriculture and Nutrition Linkages

The economic and policy context surrounding agriculture-nutrition linkages has been changing rapidly during the past 25 years. This chapter examines four types of change that drive behaviors among producers and consumers and that together are transforming the agricultural landscape and its relationship to human nutrition.

- Agricultural policy
- Agricultural technology
- Food marketing systems
- Food consumption patterns

These changes affect the broader context in which nutrition-oriented agricultural interventions are implemented. They also affect each of the pathways through which agriculture affects nutrition, notably consumption of own-production, producer incomes, and food prices. The effects on these three pathways, which are the subject of this chapter, are summarized in table 5.

AGRICULTURAL POLICY

Until the 1970s and 1980s, domestic agricultural and food policies in many developing countries assumed an interventionist stance. The policies applied principally to staple crops, but extended outward to agricultural products generally, including fruits and vegetables. Government agencies often controlled trade in food products with laws that limited private trading, notably by restricting the purchase or movement of production output by private firms. These interventionist policy regimes tended to discriminate against agriculture and in favor of urban-industrial growth. Examples of such policies included import substitution, financial-sector controls, and overvalued exchange rates as well as taxing agriculture to subsidize urban and industrial development (Christensen and Witucki 1982; World Bank 1986; Krueger, Schiff, and Valdes 1991; Bhagwati 1993; Delgado 1995; Sanders et al. 1996; Sahn et al. 1997; Teranishi 1997; Badiane 2000; Thorbecke 2000). Agriculture was seen primarily as fuel for industrial growth rather than as a source of growth in itself.

Since that time, agricultural policy in most developing countries has undergone a major paradigm shift as part of what is often termed “globalization.” Although the role of the government in food markets continues to be extensive, governments have dismantled state marketing mechanisms and liberalized trade and investment. In addition,

Table 5 Potential Effects of the Changing Context on Pathways Linking Agriculture and Nutrition

Changing Context	Pathways linking agriculture and nutrition From increased production to		
	Increased consumption	Increased income	Lower food prices
Agricultural Policy	Can alter the incentives for sale of food products into the marketplace, thus altering availability for own-consumption	Can have the effect of increasing or decreasing producer incomes	Can have the effect of increasing or decreasing consumer food prices
Agricultural Technology	Can expand the range of crops available for own-consumption	Impact of agricultural technology on labor demand can be positive or negative; that affects producer incomes.	Rising productivity and new crop varieties arising from agricultural technologies can lead to lower food prices.
Food Marketing Systems	New marketing arrangements can alter producer incentives to sell food into the marketplace rather than produce for own-consumption.	Rising power of private marketing institutions can affect producer incomes positively or negatively.	Can have the effect of increasing or decreasing consumer food prices
Food Consumption Patterns	Less food now consumed from own-production. Pattern of consumption diversified because of demonstration effect	Can create opportunities for income generation by small farmers	Can have the effect of increasing or decreasing consumer food prices

Source: Authors.

through changes in exchange rate regimes and trade liberalization in the nonagricultural sector, the levels of taxation or “disprotection” of the agricultural sector have declined over time. Overall, private markets have assumed greater importance relative to state intervention.

Trade liberalization has been a particularly important policy change. Until the 1970s and 1980s, developing-country governments favored restricting international food trade to limit import competition and to prevent export-driven increases in food prices. This changed with the culmination of the Uruguay Round and the Agreement on Agriculture in 1994, which resulted in the development of a more open multilateral system for trade in agricultural products. Although the pace of reforms would later stall during the Doha Round of the World Trade Organization a decade later, a number of North-South preferential trading arrangements would still come into existence. Preferential trading arrangements have signifi-

cantly altered the effective trade regime for agricultural producers in many countries as well as the availability of products for consumers. Two prominent examples are the European “Everything but Arms” initiative and the US “African Growth and Opportunity Act,” both of which give expanded access to selected low-income countries. Some countries such as Bangladesh have also attempted unilateral liberalization. Regional trade agreements have also been developed, increasing at a rate of 15 percent in the 1990s (FAO 2004). These changes have resulted in a rising share of output being traded, as well as changes in the composition of trade. The average tariff on nonagricultural goods fell from about 40 percent in 1947 to 4.7 percent by the end of the Uruguay Round in 1993. Since 1971, global agricultural exports have grown

7 These calculations are based on FAO statistics for agricultural exports and the World Development Indicators for agricultural value added and the US dollar GDP deflators.

at 3 percent a year in real terms, while agricultural production has grown at 0.7 percent a year. As a result, the share of agricultural production that is exported has doubled, rising from 19 percent in 1971 to 40 percent in 2003.⁷

This shift in agricultural policy has important implications for nutrition. The increased market orientation of agriculture has altered the incentives for food producers to sell their products in the marketplace, thus altering availability for own-consumption. There are also important implications via the food price pathway and the income pathway, as discussed below.

Agricultural policy changes and food prices. Agricultural policy can affect food consumption patterns by creating incentives, disincentives, or both to the production of different foods, and therefore their relative availability and prices (Nugent 2004; Hawkes 2007a, 2007b). Liberalization of agriculture and trade policy has particularly strong implications. In theory, liberalization can lead to decreases or increases in consumer prices. At the national level, the impact on commodity prices will vary across commodities, depending on whether the country is a net importer or a net exporter of that commodity. The observed pattern of trade in which developing countries are net exporters of high-value, micronutrient-rich crops implies that consumer prices are higher for those products than the prices that would prevail in a closed economy. The reverse would hold for the supply of macronutrients because the developing countries broadly are net importers of grains.

Trade reforms affect food prices in part by affecting the amount of food available. Thus, the price of importable food products decreases with trade liberalization (as supply increases with imports) and the price of exportable food product increases with liberalization (as domestic supply decreases). Box 4 presents a synthesis of cases in South Asia that have undergone changes in their trade policies and have experienced different outcomes in food availability for consumption. The relationship between trade reforms and food availability, accessibility, and stability has been explored by FAO in a series of 15 country case studies (Thomas 2006). Enormous differences in outcomes were observed between the 15 countries, some attributable to the nature and extent of the reforms themselves, others attributable to the heterogeneity of initial conditions. Modest growth in

food availability was recorded in Kenya and Malawi, whereas in China, per capita supplies of the principal nutrients improved dramatically. In Tanzania, per capita availability of the main nutrients declined following reform. The effects of structural policy reforms on household incomes tend to rely on the overall response of the economy to the reforms. In countries in which postreform economic growth was inadequate, poverty was likely to deepen. Overall the study concluded that food availability, accessibility, and stability could be worsened in the short to medium term if trade liberalization is introduced without a policy package designed to offset its negative effects—especially for countries in earlier stages of economic development. The Economic Research Service of the U.S. Department of Agriculture has also examined this question. The service used a computable model to assess the direct impact of agricultural liberalization on the “nutritional gap” (i.e., per capita food availability relative to minimum nutritional requirements) in 67 low-income countries (Trueblood and Shapouri 2001). According to the baseline forecast from the model, the nutritional gap was projected to be 21.9 million tons in 2010. In terms of the impact on prices, the study projected that long-run, real-world food prices would rise by about 12 percent and that developing country exports would increase by about 30 percent following global trade liberalization. When fed into the model, these price changes led to a reduction in nutritional gaps in the studied countries by 6.4 percent. These gains are relatively modest because of the lack of producer response in developing countries, the declining share of agriculture in total exports, and the small share of food imports in total domestic food availability.

Agricultural policy changes and producer incomes: In theory, the impact of trade liberalization on producer incomes depends on whether the sector in question was protected or taxed initially. Sectors that were protected initially would face greater import competition and could lose out, whereas those that were taxed initially could benefit from new opportunities from trade liberalization. Theoretically, if resources (including labor) could be effortlessly transferred across sectors, then the transition following trade liberalization would be less detrimental to household income, with subsequent implications for food consumption. In reality, the structural features of the de-

Box 4 Trade Liberalization and Food Availability: Synthesis of Cases in South Asia

Between 1971 and 2002 there was a clear increase in the availability per capita per day of calories and fat in South Asia although the availability of proteins increased only marginally. The exceptions are Bangladesh with respect to proteins and Sri Lanka for fat, both of which have remained stagnant over time. In Bangladesh, significant increases in the availability of calories and fats took place in two periods, once during the late 1980s and then during the late 1990s. In India, significant increases in the availability of calories and proteins occurred during the 1980s, and increases in the availability of fats occurred fairly steadily from the late 1970s. Nepal witnessed a pattern similar to India's, except that steady increases in the availability of fats started from the early 1980s. In Pakistan, a steady increase in the availability of all three nutrients has been seen over time, except for two phases of deterioration in calorie and protein availability from 1976 to 1985 and again during the early years of this century. Sri Lanka presents a picture of a fluctuating scenario, with improvement, stagnation, or deterioration for the three nutrients.

Nepal is the only country in the region in which food import dependency rose in the 1980s and has remained stable at modest levels subsequently; Sri Lanka witnessed the sharpest fall in import dependency. But during this period, Nepal achieved the highest levels of availability per capita per day of both calories and proteins from levels much lower than the rest of the countries, whereas Sri Lanka has slipped in its rankings in the case of calories and fats. Only in Nepal did availability of cereals grow faster than domestic production. In Bangladesh, availability grew at the same rate as production, whereas in India,

Pakistan, and Sri Lanka, availability has grown at a slower rate than domestic production. Underlying the differential rates of growth of production and availability is the role of stocks and trade in determining availability and consumption.

Could these differences in the nutrient availability across countries of South Asia be explained by the differences in their policy regimes? Did the very policies that helped improve food self-sufficiency hurt household-level food and nutrition security? The case of cereals suggests that this could possibly be the case, although the relationship between nutrient availability and trade reforms presents mixed evidence from South Asia. Except in Nepal, significant stock accumulation has taken place in all countries through the use of price support/buffer stocking schemes. India, Pakistan, and Sri Lanka continue to pursue stocking policies vigorously. Nepal had only a notional buffer stock policy, and in Bangladesh, the importance of such interventionist domestic policies waned over time.

In regard to trade flows, India turned from being a net importer of cereals into a net exporter beginning in the 1990s, and Pakistan recently became a net exporter. Although net imports of cereals as a percentage of availability declined steadily in Sri Lanka, it has remained more or less stable over time in Bangladesh. Nepal is the only country, having been a net exporter of cereals in the 1970s, that became a net importer beginning in the 1980s, although the share of net imports in availability is just 1 percent. Nepal's porous border with its main trading partner, India, effectively renders its trade regime nearly free, despite the low/moderate tariffs that it maintains. Similarly, Bangladesh's border with India is also relatively

(continued)

veloping countries imply that resources are not freely mobile across sectors and those employed in the protected sectors would, in fact, suffer likely job and income losses due to trade liberalization. When the group of losers from trade liberalization includes a large section of the poor, as may well be the case in many developing coun-

tries, then trade liberalization can result in a rise in poverty, at least in the short run. The impact of trade liberalization on income is therefore likely to differ, depending on the initial status of the country (as a net importer or net exporter) and then within the country across net producers and consumers.

Box 4 Trade Liberalization and Food Availability: Synthesis of Cases in South Asia, Cont.

porous, although to a lesser extent. Sri Lanka, an island nation, does not have a porous border like Nepal or Bangladesh; hence, the tariffs it maintains do perhaps bind its trade flows.

Reforms in these countries started at different times. Bangladesh started trade liberalization from the early 1980s; India, from the early 1990s (with little agricultural trade liberalization coming even later); Nepal, from the early 1990s; Pakistan, from the 1980s; and Sri Lanka, from the late 1970s. Reforms initiated in the early 1980s in Bangladesh seem to have accelerated the growth in per capita availability. In India, the improvement in per capita availability occurred primarily during the 1980s, that is, earlier than the reforms. Although there was hardly any change in the 1970s and in the early 1990s, the late 1990s witnessed a decline in the per capita availability of cereals, in part due to a rise in cereals exports following the liberalization that started in the 1990s. In Nepal, the growth pattern of per capita availability closely mirrors that of

India. That is expected; given that Nepal is a landlocked country and India is its main trading partner, the food price and supply would depend on the situation prevailing in India.

For Pakistan and Sri Lanka, no obvious pattern emerges between trade reforms and per capita availability of cereals. The decline in per capita availability of cereals in Pakistan started in the 1970s, even before the initiation of trade reforms in the 1980s, when the decline continued to occur. The 1990s was a period of recovery, and by 2002, the level of availability per capita was more or less back to the levels of the 1971–75 period. Sri Lanka presents a picture of nearly static availability per capita over the years, except for a brief rise in the late 1970s, followed by a fall to earlier levels in the 1980s. Although the 1990s witnessed a small decline in the per capita availability, the early years of this century have seen a recovery back to the levels that prevailed in the early 1970s.

Sources: Ahmad et al. 2006; Chowdhury et al. 2006; Jha and Srinivasan 2004; Pyakuryal et al. 2005; Ravi et al. 2004; Weerahewa 2004.

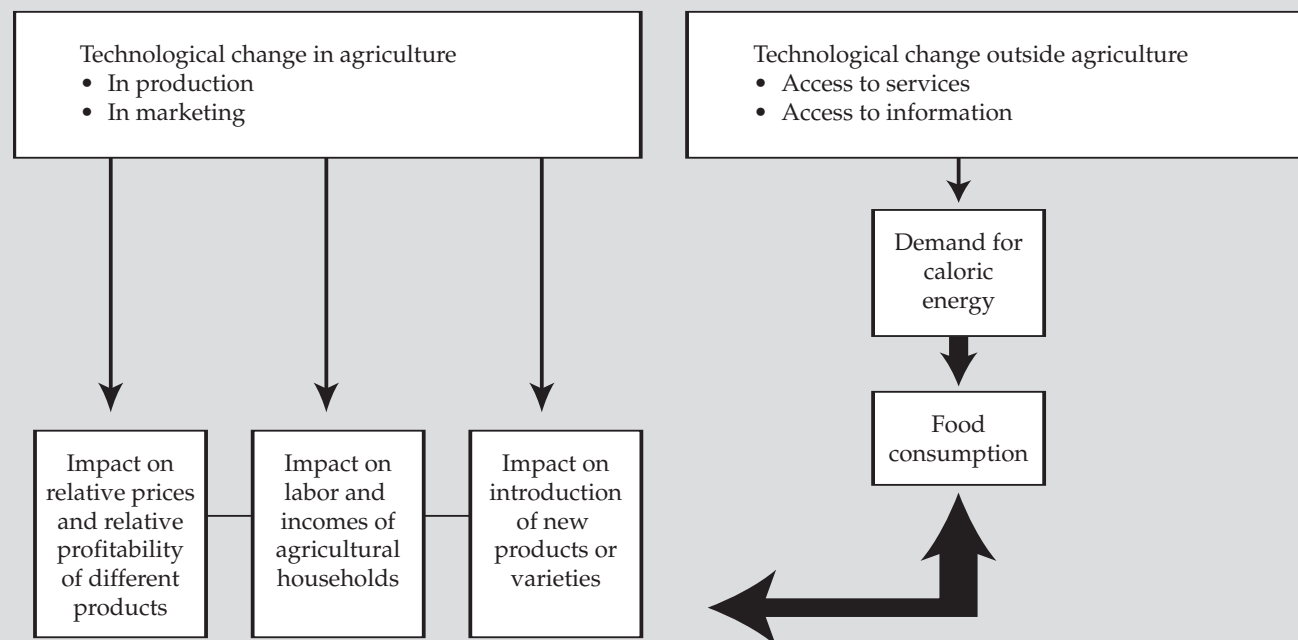
AGRICULTURAL TECHNOLOGY

The growth of agricultural technology has been dramatic during the past 25 years. Developments that carry particularly important implications for food availability and patterns of food demand and consumption are plant breeding—focused mainly on increasing yield and productivity, but more recently on increasing crop nutrient content—and technologies related to food processing and marketing, such as those that maintain a cold chain from farm to plate. The effects of developments in agricultural technology on food production and consumption can be classified into three impacts (shown in Figure 6). The first is the impact on relative prices and on the relative profitability of different products for producers. The second is technology's impact on the labor and incomes of agricultural households. The third is the role of technology in introducing new food products with different nutritional properties.

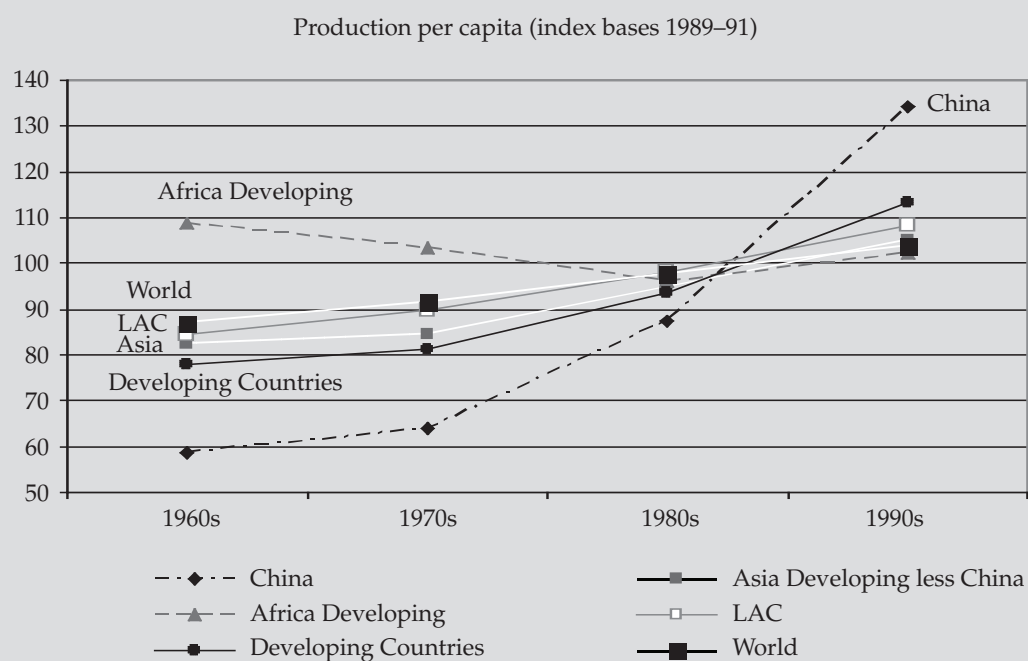
Technology's impacts on relative prices and relative profitability of different food products. Agricultural

technology has long focused on plant breeding and varietal improvements designed to raise productivity and yields. In the past 50 years, technological change has led to spectacular outcomes, such as the Green Revolution in wheat and rice and the broad acceptance of single-cross hybrids in maize (Baenzinger 2006).

In 2003 a study published in the journal *Science* presented an analysis of the contribution of Green Revolution crop breeding technologies to productivity by crop, region, and by decade between the 1960s and 1990s. Figure 7 shows the evolution of food production per capita. With the exception of Sub-Saharan Africa in the 1980s, the production of food per capita shows an increasing trend that can be largely attributed to new crop varieties (Evenson and Gollin 2003). During the same time period, foods not subject to varietal improvements saw little or no productivity change and as a result have risen in price and been removed from many production portfolios. The case of pulses in India, which have seen little if any varietal improvement, sharply rising relative prices, and declining aver-

Figure 6 Potential Impact of Technological Changes on Food Production and Consumption

Source: Authors.

Figure 7 Changes in Food Production per Capita over Time

Source: FAOStat (adapted from Diao et al. 2005).

Box 5 Decline in Consumption of Pulses in India: The Effect of Technology and Domestic Policies

Pulses are consumed by almost all categories of households in India. Many consumers in India rely on cereals and pulses as primary sources of protein and calories. This is particularly important in a country in which many consumers exclude meat for religious reasons or for reasons of affordability. According to Price et al. (2003), stagnant production and a rising population caused the per capita availability of pulses in India to fall between 1979 and 2001. That is in sharp contrast to the case of rice and wheat, the availability of which rose steadily. Moreover, the decline occurred alongside increases in per capita income. This suggests that relative prices and the availability of substitutes were the factors behind this trend.

Indeed, index data on wholesale prices in India indicate that between 1980 and 2000, prices for pulses rose significantly relative to other food items. The annual growth rate in pulse prices was 2.1 percent, five times the growth rate in wheat prices and four times the growth rate in rice prices. During the same time period, the annual growth rate in the prices of edible oils and eggs was negative. Consumption

data show that with changes in relative prices, households exhibit significant substitution toward alternative food products, and to a lesser extent, substitution among different pulse varieties.

Although several factors have been at play in causing low levels of pulse production in India, the lack of technological progress in pulse production is unquestionably one of them. With regard to trade policy, no other major food item in India has had a consistently more open import regime. Still, pulse imports have been low. Part of the reason is the lack of production of the preferred, low-cost varieties by large suppliers like Canada and the United States. Moreover, the logistical costs for exporters in these distant countries tend to be high, despite the low tariffs and complete lack of nontariff barriers.

More important, little varietal improvement has occurred in pulses domestically. Yields have remained more or less flat since the 1970s. In addition, government policies have tended to favor cereals such as rice and wheat through support pricing and input subsidies. That has further reduced the acreage under pulses in India.

Source: Price et al. 2003.

age consumption, provides a particularly useful illustration (box 5).

In contrast, real food prices of the crops subject to productivity gains declined during the 1980s and 1990s, for the world as a whole and for most developing countries. Using the IMPACT model developed by the International Food Policy Research Institute (IFPRI), analysts simulated what food prices would have been in the absence of the Green Revolution. The simulated prices were used to calculate the economic availability of food and, in turn, the impacts on childhood malnutrition. According to the study, had the Green Revolution not occurred, the proportion of malnourished children in developing countries would have been 6 to 8 percentage points higher than it is. In South Asia, the percentage would have been 12 to 15 points higher (Evenson and Gollin 2003).

Many other agricultural technologies have implications for food prices. For fruits and vegetables,

for example, postharvest technology and marketing are likely to play a more important role in reducing prices. Estimates from the Rabobank (2006) conjecture that postharvest losses lead to the spoilage of up to 30 percent of the fruits and vegetables produced in India. Postharvest losses in fruits and vegetables were as high as 50 percent in Malawi in 2001 (Mwangwela 2001). In such a scenario, improved postharvest technology could significantly affect marketing costs and consumer food prices.

Technology's impacts on labor and incomes of agricultural households. Technological change affects the demand for agricultural labor and thus the income of farm and nonfarm households in rural areas. There are a number of different impact scenarios. As production expands there may be an increase in the demand for labor that has a positive effect on the incomes of landless laborers. Alternatively, technological change that leads to more mecha-

nization could reduce labor demand. It is possible that labor-augmenting and labor-saving technologies could be introduced simultaneously, making the impact ambiguous. Technological change may also depress prices and, under conditions of low demand elasticity, negatively affect the incomes of some farmers, particularly those who do not adopt the technology or those who adopt it late.

A 1993 report (Kennedy and Bouis 1993) published by the International Food Policy Research Institute provided a number of such examples in which agriculture-nutrition linkages worked through changes in labor demand. An earlier study published in 1987 had examined households that adopted modern rice varieties in the North Arcot District of Tamil Nadu between 1973 and 1983. In those households, the real value of consumption had doubled during that period, with a shift toward more varied diets as demand for labor increased during the early phases of the Green Revolution (Hazell 1987). Subsequent phases of the Green Revolution, however, saw increasing trends toward mechanization and related declines in labor demand (Binswanger and von Braun 1991). The studies examining the relationship between agricultural commercialization and nutrition outcomes summarized in chapter 3 included some projects involving technology adoption. Overall, those studies found that although income and food expenditures were affected, impacts on child nutritional status were limited and mixed. In a more recent study, women with the most access to new rice varieties experienced less seasonal fluctuation in body weight, 1.1 kilograms compared with a 2.9-kilogram fluctuation for women with the least access (Kerr 2006). An earlier study of pregnant women in the Gambia indicated that less body weight fluctuation between the dry season and the rainy season, combined with an additional 500 calories a day, would likely lead to improvements in birth weights (Lawrence et al. 1987). These studies dealt with staple crops. For perishable crops like fruits, vegetables, livestock, and fish, access to postharvest infrastructure and affordable technology are also likely to affect farm incomes.

Technology and the introduction of new food products. Agricultural technologies can affect the nutritional properties of foods by increasing micronutrient content, for example through biofortification. Biofortified crops can benefit nutrition through the own-consumption pathway when

they are consumed by producers, or through the income pathway if sold, or the food-price pathway if it makes micronutrient-rich foods more available in the marketplace.

Plant breeding technologies can also expand the range of crops available for people to plant in homestead gardens), thus again bringing potential nutritional benefits through the own-consumption and food price pathways. For example, a joint FAO (Food and Agriculture Organization) and AVRDC-RCA (Asian Vegetable Research and Development Center–Regional Center in Africa) project to reduce vitamin A and iron deficiencies sought to stagger the production of different varieties of indigenous vegetables, many of which are seasonal, to provide greater continuity throughout the year (Aphane et al. 2003).

FOOD MARKETING SYSTEMS

The past 20 years have seen substantial change in the ways that food is marketed from farm-to-plate. An important development has been the rise of domestic and international marketing systems controlled by private actors rather than state marketing mechanisms. More open trade and investment have made buying companies, products, and services easier across national borders, so creating incentives for agri-food companies to grow and transnationalize through vertical integration and global sourcing. The modernization of agricultural marketing channels has had huge implications for agricultural producers via the income and own-consumption pathway. The increasing importance of private institutions has strong implications for producers' incomes, and new marketing arrangements have altered their incentives to sell food into the marketplace relative to producing for own-consumption. The process has also had important implications for food consumption patterns by altering the range and mix of products available in the marketplace, the price of the food, and the way it is sold and promoted, all of which affect consumption decisions. Three changes in the marketing chain are particularly important from a food consumption perspective: food processing, food retail, and food exports.

Food processing. Food processors have emerged as important actors in the agricultural marketing chain. Instead of selling crops direct for preparation in the home, agriculture increasingly supplies

Table 6 Annual Average Growth in Retail Sales of Packaged Foods, 1996–2002

Country group	Per capita retail sales of packaged foods 2002 (\$)	Total retail growth of packaged foods 1996–2002 (%)	Per capita growth of packaged foods (%)
High income	979	3.2	2.5
Upper middle income	298	8.1	6.7
Lower middle income	143	28.8	28.1
Low income	63	12.9	11.9

Source: Euromonitor data analyzed by Gehlhar and Regmi 2005.

raw materials to the food processing industry for the production of durable foods. This has implications for nutrition through the food price pathway, because it has altered the availability and prices of processed foods in the marketplace. As food processing has become a more important component of the marketing chain, the share of processed food in total consumption has risen. Global sales of processed foods are US\$3.2 trillion, of which about US\$2.0 trillion is spent on packaged food and US\$1.2 trillion on beverages. These global figures are strongly affected by demand in industrialized countries, where consumers spend about half their food budget on processed, packaged foods (Minot and Roy 2006). Consumers in lower-middle-income countries spend less on processed foods—about one-third, while in low-income countries like Kenya, India, and Vietnam, the proportion is less than 15 percent (Gehlhar and Regmi 2005). However, what is notable is that the rate of increase of expenditure is far higher in developing relative to developed countries, as shown on Table 6. In India, recent evidence points to a notable shift toward processed foods over time. A demand model developed at the International Food Policy Research Institute (IFPRI) projects that Indian expenditures on processed foods will rise faster than expenditures on both total food and nonfood goods (Ravi and Roy 2006).

Food retail. Agricultural producers now sell more and more of their products directly to large-scale retail outlets (supermarkets, hypermarkets), rather than to local markets or to wholesalers. Supermarkets have been growing rapidly in recent years in developing countries, driven largely by the growth of transnational enterprises (Table 7).⁸ Among

developing countries, supermarkets' share of the retail food market is highest in middle-income countries such as Brazil, Argentina, and Thailand, and lowest in low-income Asian countries, such as Bangladesh and Vietnam. Supermarkets in developing countries are better able to handle both processed foods and fresh products, but in most developing countries, processed foods tend to have a smaller share of the market than fresh fruits and vegetables.

These changes have implications for nutrition through the food-price pathway. Supermarkets have the potential to increase or lower food prices (Kuipers 2005; World Bank 2006). Because of higher marketing efficiency, food prices in supermarkets could be lower. At the same time, there could be a premium on food prices as a result of the convenience and the standards that the supermarkets provide. Also, if the growth of supermarkets leads them to gain dominant market power, they could exploit the inelasticity of food demand to increase prices (Minot and Roy 2006).

Two empirical facts are important to consider when trying to assess the potential impact on food prices. First, supermarkets have not yet become the supply source for all consumers in developing countries. There is ample evidence of supermarkets and traditional retail existing side by side. In many places, the emergence of supermarkets has created a segmented market, with the richer sections of the population sourcing their consumption from supermarkets and the low-income class sourcing from traditional retail. Second, in many developing

8 The data must be interpreted with caution because the definitions of supermarkets and retail sales differ across countries.

Table 7 The Growth of Modern Retail in Developing Countries

Country	Year	Number of supermarkets	Share of supermarkets in total food sales	Growth in supermarkets		Information source
				Period	Annual growth rate	
Argentina	2001		57			(1)
Brazil	2001		75			(1)
Guatemala	2001		35			(1)
Mexico	2001		45			(1)
Bangladesh	2004	30	1%	1999–2004	97%	(1)
India	2000		2%	2003–2008	24–49%	(2)
Pakistan	2000	800	10%			(3)
Indonesia	2003	1,307	25%	1989–2002	15%	(4), (5)
Philippines	1995	3,989	68%	1994–2001	30%	(6)
Thailand	2004	600	54%	2001–2002	11%	(7)
Vietnam	2003	<70	<2%			(8)
China	2003	37,000	30%(urban)	1995–2002	36%	(9)

Sources: (1) USDA 2004a; (2) Chengappa et al. forthcoming ; (3) SDPI 2004; (4) Chowdhury et al. 2005; (5) USDA 2003; (6) Digal and Concepcion 2004; (7) USDA 2002; (8) Tam 2004; and (9) Hu et al. 2004.

countries, including those like South Africa, in which the coverage of retail by supermarkets is high, there is no evidence for any substantial increase in food prices.

Two empirical studies provide some insights into the impact of supermarkets on food prices. Neven et al. (2006) compared prices in Nairobi supermarkets with the prices of similar products in traditional retail. The prices of nine fresh produce items were, on average, 6 percent higher in supermarkets, and the prices of processed food products were, on average, about 3 percent lower. Consumer surveys revealed that the urban poor bought processed foods in supermarkets and fresh produce in wet markets, as would be expected, given these price relationships. A similar analysis of horticultural products in Argentina found that the prices for fruits and vegetables were, on average, 6 percent and 14 percent higher in supermarkets, respectively, relative to traditional retail outlets (Ghezan et al. 2002). However, the average price for all food and beverages was 5 percent lower in supermarkets. Despite the large market share of supermarkets in Argentina (70 percent in 2000), small fruit and vegetable shops continued to dominate horticultural retail sales. The authors cite survey results indicating that 71 percent of fresh fruits and vegetables were bought from traditional retail outlets.

Food exports. As already noted, trade liberalization has enabled a significant increase in the amount of agricultural products that are exported rather than consumed in domestic markets. The modernization of agricultural markets has also facilitated the expansion of the development and integration of international food marketing systems, including the extensive supply chains that serve large food retail industries. Trade liberalization is also associated with a shift in the commodity composition of international food trade toward higher-value products, accelerating a trend under way since the 1960s. Between the 1960s and the 1990s, grain exports fell sharply from 15 percent to 8 percent of the total value of agricultural trade (table 8). At the same time, exports of higher-value agricultural products, such as fruits and vegetables, meat, dairy products, eggs, and fish and seafood, grew from 29 percent to 42 percent of total value. The share of fish and seafood, in particular, increased from less than 5 percent to more than 13 percent of world agricultural trade.

The composition of agricultural exports has also changed in terms of the share of processed versus fresh products. It has been estimated that processed food exports grew 4.2 percent per year between 1980 and 1994—twice as fast as primary product exports (Athukorala and Sen 1998) and, according to FAO, the share of processed products

Table 8 Composition of Global Agricultural Food Exports (% of value)

	1964–73	1974–83	1984–93	1994–2003
Cereals	19.50	20.94	19.29	19.26
Pulses	1.18	1.24	1.53	1.51
Meats	9.74	10.97	13.26	13.96
Vegetable oils	5.56	7.72	8.51	10.58
Fruits	8.90	7.75	9.54	12.07
Eggs	0.87	0.85	0.79	0.66
Milk	0.22	0.39	0.70	1.19
Other	54.03	50.15	46.38	40.77
Total	100.0	100.0	100.0	100.0

Source: FAOStat 2007.

in agricultural exports increased from 41 percent in the 1980s to 51 percent in the 1990s (FAO 2004). The growth in the share of agricultural exports that are processed can be seen in almost all commodity categories. The exceptions to this pattern are fruits and vegetables. The share among world agricultural exports of both primary and processed fruits and vegetables has increased during this period, but growth in fresh fruit and vegetable exports has been greater. The proportion of processed foods that are exported does, however, remain smaller than the proportion of agricultural commodities that are exported, probably, in part, arising from the higher tariffs imposed on processed products (Gelhar and Regmi 2005).

This changing pattern of exports has implications for nutrition through the food-price pathway because it increases the availability of certain foods over others in exporting and importing countries (Hawkes 2006, 2007a, 2007b). Whereas consumers in developing countries now consume more processed foods and vegetable oils exported from developed and other developing countries, consumers in developed countries now consume more fruits, vegetables, and fish exported from developing countries. Another important trend is the increased export of animal feed, which has enabled the rapid growth of livestock production around the world. Hawkes (2007a) cites an example from Colombia, in which trade liberalization in the 1990s led to increased imports of corn for animal feed from the United States—directly stimulating the growth of the poultry industry. Subsequently, poultry prices plummeted in Colombia and consumption soared, whereas beef consumption declined.

FOOD CONSUMPTION PATTERNS

Economic growth, demographic change, urbanization, and global media and mass marketing have stimulated rapid changes and diversification in food consumption patterns. The shifting pattern is evident in increasing demand for high-value foods relative to cereals and pulses in most developing countries (Popkin 2006). Per capita consumption of cereals and pulses contracted during the 1990s, while annual vegetable consumption grew 3.7 percent; fish and seafood, 2.2 percent; and fruit and meat, between 1 percent and 2 percent (table 9). Less of this food is consumed from own-production and more purchased from the marketplace. Regionally, between 1982 and 2002, East and South Asian countries saw per capita consumption of vegetables and fruits rising quickly. Meat, milk, eggs, fish, and seafood consumption grew more slowly, but still increased more than the consumption of staples. In 2002, East and Southeast Asia exhibited the highest per capita consumption of vegetables in the developing world, at 64 kilograms per person per year, and the highest consumption of fish and seafood, at 26 kilograms per person per year.⁹ Increases in consumption of high-value food products were particularly high in China, in which, between 1962 and 2002, per capita intake of vegetables grew 4.9 percent; fruit, 8 percent; and meat, 8.7 percent. In

⁹ The FAO definition of fruits and vegetables includes root crops such as potatoes and sweet potatoes. Because these items are almost staples in some countries, the definition overstates the share of the nonstaple food.

Table 9 Average Annual Growth in Global per Capita Consumption of Various Food Items (%)

Food item	1962–71	1972–81	1982–91	1992–2002	1962–2002
Cereal (excluding beer)	0.5	0.8	0.4	–0.4	0.3
Pulses	–2.0	–1.5	–0.3	0.0	–1.0
Vegetables	–0.3	0.8	1.4	3.7	1.5
Fruits (excluding wine)	1.5	0.5	0.8	1.8	1.2
Milk (excluding butter) and eggs	0.1	0.2	0.0	0.6	0.2
Meat	1.8	1.1	1.1	1.3	1.3
Fish, seafood	2.0	0.8	1.0	2.2	1.4
Years for vegetable oils				1990–95	1996–2004
Vegetable oils				1.35	2.84

Source: FAOStat 2005.

Note: Consumption is measured in kilograms. Data for fish and seafood are up to 2001.

2002, the Latin American and Caribbean region had the highest annual per capita consumption of fruits in the developing world, at 102 kilograms per person; the highest meat consumption, at 61 kilograms; and the highest milk and eggs consumption, at 113 kilograms. Processed food consumption has risen in all regions.

As part of these trends, the consumption of high-calorie, nutrient-poor foods is also rising, notably of vegetable oils, meat, processed foods, and food prepared away from home. These dietary changes toward high-calorie, nutrient-poor processed and prepared foods are accompanied by changing, generally lower, levels of physical activity, as occupations shift to service-sector jobs, especially in urban areas. In these settings, consumers in developing countries are now experiencing what is termed the “nutrition transition” toward some of the problems as well as the benefits of populations in industrialized countries: the rise in overweight, obesity, and associated chronic diseases like heart disease, hypertension, and diabetes (Popkin 1999, 2002; Popkin and Du 2003).

As consumption patterns have changed, so have agricultural production patterns. Global production of oil crops, for example, increased by about 1.9 million tons annually between 1990 and 2005. Production of vegetables has also increased markedly, growing at 4.2 percent per year. An increasing share of arable and permanent land is now used for vegetable and fruit production, and almost all of this increase is occurring in developing countries (Minot and Roy 2006). The share of the

arable land used for vegetable and fruit cultivation has remained stable in the developed countries, but has increased markedly in most developing regions, as reflected in table 10. The share of land used for cereals and pulses production declined in developed countries and in Latin America, but remained constant or slightly increased in Asia and Africa, implying that fruits and vegetables have replaced other crops. The growth in grain production declined from more than 4 percent annually in the 1960s to less than 1 percent in the 1990s (table 11). The production of high-value agricultural commodities in contrast has grown between 2 percent and 5 percent annually during the past 40 years, with the exception of milk, which grew between 1 percent and 2 percent.¹⁰

These changes in production patterns are in part a response to changes in consumer demand, in part a stimulator of consumer demand (Hawkes 2007a, 2007b). They have implications for nutrition through the food-price pathway and also through the income pathway because smallholder production that answers the growing demand for high-value food sources may have a positive effect on

¹⁰ The shift in Chinese production has been particularly dramatic. China reduced the share of arable land in cereals by half between 1975 and 2002, while grain productivity almost doubled. The share of land used for fruit production has increased from 2 percent in the late 1970s to 6 percent in 2002. Similarly, for vegetables, land use has risen from 3 percent in the mid-1970s to 13 percent in 2002. In 2002 China accounted for 47 percent of total world vegetable production (in volume terms) and 15 percent of fruit production.

Table 10 Average Annual Share of Arable and Permanent Land Used for Harvest (%)

Agricultural item and region	1962–71	1972–81	1982–91	1992–2002	1962–2002
Cereals^a	48.4	49.5	47.6	45.0	47.6
Africa	38.9	37.2	40.0	44.7	40.3
East and Southeast Asia	54.4	55.1	53.8	53.8	54.3
Latin America and Caribbean					
Caribbean Caribbean	35.4	35.1	33.8	29.4	33.3
South Asia	60.2	62.7	63.4	62.2	62.1
Developed countries	43.1	44.8	42.5	38.1	42.0
Pulses^a	4.8	4.3	4.5	4.5	4.5
Africa	5.9	5.5	5.7	7.9	6.3
East and Southeast Asia	2.2	2.5	2.7	3.6	2.8
Latin America Caribbean	5.7	5.7	6.1	5.0	5.6
South Asia	13.0	12.8	12.9	12.1	12.7
Developed countries	2.0	1.4	1.7	1.4	1.6
Fruits (excluding melons)^a	1.9	2.2	2.6	3.1	2.5
Africa	3.0	3.5	3.9	4.2	3.7
East and Southeast Asia	2.5	2.8	3.2	3.7	3.1
Latin America Caribbean	2.2	2.7	3.6	4.1	3.2
South Asia	1.1	1.2	1.6	2.1	1.5
Developed countries	1.8	1.9	1.9	1.9	1.9
Vegetables (including melons)^a	1.7	1.7	2.0	2.6	2.0
Africa	1.4	1.6	1.9	2.2	1.8
East and Southeast Asia	2.8	3.0	3.1	3.4	3.1
Latin America Caribbean	1.2	1.1	1.2	1.3	1.2
South Asia	1.9	2.3	2.7	2.9	2.4
Developed countries	1.2	1.2	1.2	1.2	1.2

Source: FAOSTat 2005.

^aData correspond to world average.

the producer's consumption by raising income. For example, in South and Southeast Asia, diversification into high-value food commodities led to the development of innovative supply chains, opening new prospects for augmenting income, generating employment, and promoting exports (Barghouti et al. 2004; Pingali 2004; Deshingkar et al. 2003; Pokharel 2003; Wickramasinghe et al. 2003; Goletti 1999). Food security, moreover, improved in regions in which agricultural diversification took place in favor of horticulture, animal husbandry, and aquaculture (Barghouti et al. 2005; Dorjee et al. 2002).

From the perspective of poverty reduction, diversifying production toward high-value crops is particularly appealing. Most high-value food commodities such as fruits, vegetables, poultry, and

fish are labor-intensive, have low gestation periods, and generate quick returns. These qualities serve to make them highly suitable for smallholders, representing an often perfect opportunity to utilize their surplus labor and augment their incomes (Barghouti et al. 2004; Weinberger and Lumpkin 2005). Whether a smallholder-dominated economy can actually diversify and whether smallholders participate substantially in the diversification of production toward high-value products is context specific. A 2006 assessment of diversification toward high-value crops in India from the point of view of participating smallholders found evidence that the probability of a household diversifying into vegetable cultivation is higher for smaller farmers (Birthal et al. 2006). Vegetable cultivation was preferred over fruit cultivation, which

Table 11 Worldwide Annual Average Growth in Food Production (%)

	1962–71	1972–81	1982–91	1992–2002	1962–2002
Africa	38.9	37.2	40.0	44.7	40.3
Cereals (excluding beer)	4.1	2.4	1.5	0.7	2.1
Pulses	0.6	-0.2	2.9	0.4	0.9
Vegetables	1.7	2.7	3.2	5.2	3.2
Fruits	3.4	2.1	1.8	2.8	2.5
Milk (excluding butter) and eggs	1.5	1.8	1.4	1.3	1.5
Meat	3.9	2.9	2.9	2.7	3.1
Fish and seafood	5.4	1.4	2.8	2.9	3.0
Vegetable oils	4.11	4.25	4.07	4.42	4.35
Oil crops	3.30	3.96	3.31	3.90	3.63

Source: FAOStat 2005.

Note: Production is measured in metric tones. Vegetables include root crops such as potatoes and cassava. Fish and seafood data pertain to 1962–2001.

is generally less labor-intensive and more capital-intensive (with respect to start-up and working capital); both of these characteristics are to the disadvantage of small farmers.

The transition toward high-value agriculture is, however, not without constraints, especially for smallholders. When the high-value commodities are products the farmers have not grown before, they will lack information on production methods, marketing opportunities, and the probable distribution of net returns. This problem can be particularly acute when producers have to satisfy highly specific quality and food safety requirements (Minot and Roy 2006). Larger farmers are also often better able to bear the risks associated with producing and marketing high-value commodities. Furthermore, for a small farmer to allocate land to a commercial crop may imply depending on market purchases to meet food requirements, an additional source of risk. Some high-value agricultural commodities also require significant investment, including the use of specific inputs. Fruit production involves planting trees and waiting 3–5 years for them to begin producing. Farmers in developing countries, particularly poor farmers, often lack the savings or access to credit needed to make these investments. In the case of highly perishable high-value commodities, production locations near markets and good marketing infrastructure are particularly important (Torero and Gulati 2004). Small farmers are also less likely to enjoy access to postharvest technologies. Yet the competitiveness

of small farmers relative to large farmers is not fixed and can change over time, usually as a result of changes in physical, human, or social capital. Farmers may acquire new equipment or build physical capital, like irrigation works, that reduces the cost of production. Farmer's skills and human capital change over time as a result of learning-by-doing, aided in some instances by technical assistance provided by buyers (Minot and Roy 2006).

CONCLUSIONS

Changes in agricultural policy, technology, markets, and associated changes in food consumption patterns are affecting the dynamics of the pathways between agriculture and nutrition. Today, the more market-oriented nature of agricultural policies means that agricultural technology and markets play a more important role in determining food prices and rural incomes, and more food is consumed from the marketplace rather than from own-production. The greater market orientation of food production and consumption has increased the bidirectional links between agriculture and nutrition: agriculture still affects nutrition, but food and nutritional demands increasingly affect agriculture (Hawkes and Ruel 2006b). It is a twofold process. First, the increasing importance of the cash economy arising from changes in agricultural policy, technology, and markets, and from rising incomes and urbanization, is increasing the power of consumers in the marketplace. Second, the rise of food

marketing institutions, such as food processors, retailers, and exporters, is reducing the power of agricultural producers in the agricultural supply chain.

The rising role of the market has implications for the relative importance of each of the pathways between agriculture and nutrition: in general, the link between agriculture and nutrition is becoming more distant as income and food prices become more important in determining food consumption patterns relative to own-production. Agricultural programs with nutritional objectives need to take this changing context into account. With the rising role of the consumer in the marketplace, there are

more opportunities for nutrition-focused agricultural interventions to improve the nutrition of net food consumers rather than just net producers. There are also more opportunities for changing food consumption patterns among food consumers to be exploited as a means of indirectly improving nutritional outcomes among producers (via income and price). Although not dealt with in this chapter, it would also be important to take into account the impact of changing contexts on the empowerment of women agriculturists and the development of human capital, given their critical role in improving nutritional outcomes.

Institutional Frameworks for Action in the Agriculture Sector to Address Undernutrition

The viability of using agricultural interventions to improve human nutrition outcomes has been empirically established by case studies and analyses like those presented in earlier chapters. These provide important precedents with valuable lessons for the planning and design of agricultural programs and interventions. While nutritional status itself is an individual-level attribute, the determinants of nutritional status extend far beyond the control of the household of which the individual is a member. Institutions are identified as “basic” determinants of nutritional status in the UNICEF conceptual framework presented in chapter 2. Government institutions establish policies and priorities and implement programs that affect nutritional outcomes at the aggregate national as well as at the household and individual levels. They can therefore be instrumental in ensuring that agricultural programs are effective in meeting national nutritional goals.

Agriculture ministries clearly have a central role to play in scaling up pilot agricultural programs and interventions, but experience has demonstrated the insufficiency of approaching nutrition entirely from the production side. Nutrition is, of course, also a consumption-side issue. Health and education, in particular, pertain to nutrition in relation to their essential roles in human capital formation and in human development. Yet prescribing systematic coordination between different sector institutions as a means of achieving a more comprehensive approach to improved nutrition is problematic, given the bureaucratic barriers that characterize the administrative division of responsibilities and jurisdictions between them.

This chapter examines the barriers that inhibit sectorally-defined institutions from organizing and carrying out joint cross-sectoral efforts to improve nutrition outcomes at a national level. It also identifies possible opportunities to work around these barriers to achieve greater impacts that no one sectoral institution is capable of. Its focus is on government institutions, based on the assumption that governments are chiefly responsible for providing infrastructure, resources, and services to promote and maintain the social and economic welfare of its citizens. The focus on government institutions is not to suggest that nongovernmental actors cannot make important contributions to improved nutrition. Nongovernmental organizations often provide many of the multisectoral goods and services that the undernourished require. Indeed, nongovernmental organizations were responsible for the success of a number of nutrition-oriented agricultural interventions reviewed in this report. Detailed analysis of the specific role of nongovernmental organizations in effectively

Box 6 Situating Nutrition Administratively within the Public Sector

Within the institutional structure of most states, *nutrition* rarely stands as a sector in its own right. It typically falls somewhere within the lower organizational levels of the health ministry, often as a department in the public health subsector—reflecting a predominantly medical view of malnutrition as a public health issue. Alternatively—and reflecting the multisectoral determinants of malnutrition and its significance as a development problem—nutrition may be situated ad-

ministratively within a coordinating body led by an intersectoral agency. This agency is sometimes housed within a prime minister's office or ministry of finance or planning. In Nigeria and Mozambique, both types of institutions may be found, with that in the Ministry of Health responsible for implementation of nutrition-related public health activities, whereas strategic and policy issues are the concern of the nutrition coordinating body.

Source: Benson et al. 2004.

linking agricultural interventions to improved nutritional outcomes is, however, beyond the scope of this report.

INSTITUTIONAL BARRIERS TO COORDINATED ACTION IN NUTRITION

The conceptual framework of the determinants of nutritional status is useful in identifying the sectoral institutions that are directly relevant to improving nutrition and in mapping their roles in any coordinated efforts to address nutrition issues. However, in the details of undertaking these efforts within the bureaucracy of the state, the clarity of the framework is often lost, as barriers to mounting harmonized efforts across the various sectors of state are encountered.

“Bureaucracy” has long carried negative connotations of inflexible or convoluted procedures that impede rather than facilitate effective collective action. Yet bureaucracies have emerged as a generally successful solution to the problem of managing the activities of states and other large organizations, being organized ideally on the basis of clear goals, a rational coordinated functional specialization of subunits, formal operating procedures, and clear lines of authority. In virtually all countries, the state is organized administratively within a bureaucratic framework of sector ministries, which includes separate ministries for

health, education, agriculture, and trade. The exercise of political and administrative power follows this framework, and resource allocations, incentives, and systems of accountability are managed accordingly.

The underlying difficulties constraining agriculture and other sectoral institutions from effectively acting in concert to address the problem of undernutrition stem from the nature of the state bureaucracy. Most bureaucracies are not organized in a manner that facilitates broad, effective action across sectors to address a problem. Even though undernutrition might be the responsibility of the public sector, the sectoral organization of the public bureaucracy clearly hinders undertaking the action necessary.

To identify the bureaucratic elements that were found to impede efforts by the state to address undernutrition in a comprehensive cross-sectoral manner, an institutional study of the linkages between agriculture and nutrition was carried out in Ghana, Mozambique, Nigeria, and Uganda as a component of the Agriculture-Nutrition Advantage (TANA) project described in box 7. The study identified four particularly important overlapping barriers that prevent the problem of undernutrition from being addressed by the agricultural sector jointly with the health, education, and other relevant sectors: the resource allocation and planning processes within the bureaucracy, differing sector mandates and priorities, differing sectoral worldviews, and capacity constraints for nutritional analysis within sectors.

Box 7 The Institutional Study under the Agriculture-Nutrition Advantage Project

The Agriculture-Nutrition Advantage (TANA) project, which ran from 2001 through 2004, aimed to strengthen and expand linkages between nutritionists and agriculturists, particularly through employing gender-sensitive approaches to reduce hunger and undernutrition in Ghana, Mozambique, Nigeria, and Uganda. In each country, the project was centered on the activities of national project teams made up of agriculturists, nutritionists, and gender specialists. The project was implemented by the International Center for Research on Women in partnership with the International Food Policy Research Institute.

The objective of the institutional study under the TANA project was to assess the extent to which the

agriculture and nutrition communities in each country work as partners to reduce malnutrition, to gauge the potential gains from increased collaboration, and to understand the various constraints to such collaboration. Principally a qualitative study, the scale of analysis was at the national level in the four project countries. Key documents that focused on food, nutrition, agricultural development, and master development planning in each country were reviewed. The documentation obtained before fieldwork began served to guide the broad content of the interviews subsequently carried out. Between 30 and 40 semi-structured interviews with agriculturists, nutritionists, and policy makers were conducted in each country.

Source: Benson et al. 2004.

RESOURCE ALLOCATION AND PLANNING

Resource allocation processes of budgeting and personnel management often make it difficult to mount cross-sectoral action within a state bureaucracy. Like all economic entities, the state functions under conditions of limited resources. Consequently, each sector, in seeking to carry out its mandates, will compete with other sectors for the resources it requires. Typically, the resource allocation process of government is judged a zero-sum game. For example, a state-level nutritionist interviewed for the study in Nigeria noted that funding is at the core of why there is little interaction between the agriculture and health sectors:

“Everyone wants to be in charge. If [the Health sector] writes proposals that include some agricultural components, [the Agriculture sector] is unhappy with Health, as Agriculture feels that Health is on their turf, taking resources that should be theirs.” (Benson, forthcoming)

Moreover, if independent assessments are made of the way a sector made use of the resources it received, sector-specific criteria are generally used as the criteria. The resource allocation mechanisms provide no incentives for carrying out joint coordi-

nated activities that would achieve a higher level of impact. That being the case, the attainment of nutrition objectives will tend not to be advanced by routine sector planning mechanisms. In this regard, sectorwide approaches to planning are likely to make efforts to address undernutrition in a coordinated, cross-sectoral way even more difficult to undertake, as discussed in box 8.

SECTOR MANDATES AND PRIORITIES

Formally stated mandates and objectives are important organizing mechanisms for bureaucracies since they help to define courses of action and to distinguish areas of institutional specialization within the bureaucracy as a whole. They define the scope of action for a sector or institution and serve to identify the particular, unique competencies that the institution should possess to meet those objectives. These priorities also feed back into the planning system because they are the basis by which an institution or sector can make substantive claims on state resources. Moreover, for the individual civil servant working in a sector ministry or agency, personal incentives such as career advancement tend to revolve around the contribution that each makes to the attainment of these sector-

Box 8 Nutrition and Sectorwide Approaches to Planning

The sectorwide approaches (SWAp)s to policy formulation, planning, and implementation that have been promoted in many developing countries in recent years, including in agriculture, tend to work against necessary cross-sectoral efforts to address development problems. Yet, such SWAp)s have their own logic of effectiveness and efficiency that is difficult to reject.

Thus, in making use of them, explicit recognition of the contributions that the sector concerned can make to addressing cross-sectoral development problems, such as undernutrition, must be included in the scope of such planning exercises. Otherwise, they are likely to retard rather than foster progress in reducing undernutrition.

Source: Authors.

specific objectives, rather than broader, multisectoral development goals.

The problem for nutrition as a development priority is that addressing the problem of undernutrition may not be accepted by any one sector as a priority for which it is responsible and toward which it will allocate the resources it controls, including human resources. Particularly as doing so requires engagement with other sectors to address the problem sustainably, there are compelling pragmatic reasons for agricultural and other state institutions to judge that it should not be among their primary concerns. Improved nutrition can be defined among a set of secondary objectives for a sector. However, with multiple objectives, the chances of conflict emerging between the various objectives of a sector are more likely. Some prioritization is required. A senior agricultural researcher in Nigeria noted that agriculturists have historically been most concerned with raising yields and, second, with the profitability of farming. Certainly, they may be willing to take into account nutritional considerations, but at the end of the day, he asserted, increasing crop yields is the principal criterion used to judge the effectiveness of agriculturists in Nigeria (Benson et al. 2004). Consequently, one generally sees little evidence in the organization of the agricultural sector of any effective attention being paid to what are seen as secondary concerns, such as nutrition. Thomson (1978) notes that most national-level ministries prefer mandates that are entirely within their own sectoral sphere of influence and control. "Such circumscribed objectives are much less time-consuming and much more easily administered; rivalries, jealousies, and frustrations are lessened; and it is more satisfying to the personal ambition of the ministry staff; as credit for success

cannot be in dispute and any lack of success is more easily locked away in the ministry's cupboard." Attaining nutrition objectives clearly requires a range of action that is less neatly circumscribed within a single sector.

UNIQUE SECTORAL WORLDVIEWS

The specialized training that sector specialists receive tends to lead to discrete, nonoverlapping areas of expertise and qualitatively different worldviews. Knowledge and information that pertain directly to one's own discipline is selectively embraced, while other matters are discarded from consideration as being irrelevant to the attainment of sector objectives. Agriculture-sector objectives relate principally to increasing yields, profits, and other benefits that farmers derive as producers. As such, the language and methods that agriculturists will use, both in technical analyses and in implementation of programs, will be quite different from what are used in other sectors, such as health and education. Nutrition considerations will not fit neatly or completely into the worldview of agriculture or, for that matter, any of the core sectors of government.

The significance of this factor was observed in Mozambique, in which the Technical Secretariat for Food Security and Nutrition (SETSAN), a cross-sectoral food security and nutrition coordination body for which the Ministry of Agriculture provided secretariat services, was seen by most observers to perform its functions with regard to food security issues reasonably well. However, SETSAN had no nutrition experts among its staff and had not developed a conceptual approach to guide its

work in addressing malnutrition in the country. Consequently, despite its relative successes in addressing food security issues, because of difficulties in defining how nutritional problems in the country should be addressed, SETSAN was felt to have generally failed to coordinate cross-sectoral efforts to address malnutrition (Benson et al. 2004). The observed lack of cross-sectoral exchange or understanding as a factor impairing action to address undernutrition is not uncommon. The lack of shared perspectives, concepts, and practices frequently results in the various sectors that could work jointly to address undernutrition finding it difficult to find common ground from which to launch such efforts (Maxwell and Conway 2000).

CONSTRAINED CAPACITY FOR NUTRITIONAL ANALYSIS

Identifying the cause of a nutritional problem is central to mounting effective action to address it. Ignorance of what are the determinants of poor nutritional status and an inability to ascertain what resources and actions are needed to sustainably reduce undernutrition in a particular context are part of the explanation for the inability of agriculturists or specialists in other sectors to address the problem of undernutrition (Gillespie 2001). This was seen in all four countries in which the TANA institutional study was conducted. In Mozambique, fewer than a dozen nutritionists have master's level or higher backgrounds. In Nigeria, on the other hand, the skills of hundreds of professional nutritionists have not been applied effectively across sectors, and no positive trends in undernutrition are in evidence. In the agricultural sector in all four countries, staff with expertise in nutrition was either absent (Nigeria and Mozambique), withering (Uganda), or relatively isolated within the sector (Ghana) (Benson et al. 2004). Consequently, it is not necessarily surprising that the agriculture sector in each of these countries was seen to be contributing to improved nutrition only indirectly, if at all. Building capacity for nutrition analysis among specialists across sectors increases the probability that they will recognize the synergies that can be attained by undertaking efforts in concert.

The barriers to the agricultural sector in most developing countries accepting some of the responsibility for the problems of undernutrition in society are quite substantial. Many of these barriers are not

perverse, but reflect, first, a rational organization of the state into sectors that enable it to fulfill many of its duties and, second, the fact that nutrition concerns fit poorly within this bureaucratic organization. Barriers also emerge because the areas of expertise, the analytical methods, and the tools that agriculturists bring to the tasks with which they are charged are quite different from many of those that are needed to address undernutrition comprehensively. For a broad effort to reduce undernutrition, agriculture will need to overcome the many difficulties of communication and coordination of activities across its sectoral boundaries. In the next section, several approaches by which agriculture could institutionally play a greater role in reducing undernutrition are assessed.

INSTITUTIONAL MECHANISMS TO ENABLE AGRICULTURISTS TO ADDRESS UNDERNUTRITION

The various institutional barriers that hamper the agriculture sector from acting either alone or with other sectors to effectively and sustainably reduce undernutrition are not easily overcome. Given these constraints, it is unlikely that any single solution to overcoming them can be found in most contexts. Rather, a more opportunistic, incremental approach will most likely yield more durable reductions in undernutrition. This section considers several possible components of efforts that the agricultural sector could be a part of or undertake on its own to address undernutrition: multisectoral nutrition planning agencies; cross-sector issues as policy priorities; the inclusion of nutrition objectives in agricultural activities; community-driven development; and including nutrition topics in agricultural training.

Multisector Nutrition Planning Agencies

The cross-sectoral nature of the determinants of nutritional status has long been recognized. A common approach in grappling with the problems of mounting necessary action to address undernutrition across disparate sectors has been to establish national multisectoral nutrition planning agencies to ensure that coordinated efforts are undertaken. However, of the many such agencies that were set up in the 1960s and 1970s, few catalyzed substantial reductions in malnutrition. Without any real

authority over the range of sectors involved, they proved ineffective in coordinating efforts across these sectors. Moreover, as the political leaders who championed their formation turned their attention to other issues, the material commitment of government to address malnutrition dwindled, and the agencies were starved of operational resources. Consequently, in the following decades, coordinated cross-sectoral programs to reduce malnutrition in many countries were replaced by sector-specific projects focused primarily on technical nutrition interventions (Levinson 2000).

Such multisectoral coordination agencies remain a common feature of national strategies to address undernutrition. Few of these agencies established in recent years demonstrate any greater success than those created 30 to 40 years ago. Mozambique, Nigeria, and Uganda have established such agencies during the past 5 to 10 years, with no evidence of greater or more effective impacts on malnutrition than in Ghana, in which no such agency is in place (Benson, forthcoming). The challenges of cross-sectoral coordination remain as daunting now as they were in the past, with agencies generally lacking adequate authority or resources to introduce incentives to compel cross-sector coordination.

In reflecting on why many such attempts at coordinating efforts to address undernutrition have been unsuccessful, a clear problem relates to these agencies' scope of action. The agencies frequently have been too involved in implementation, particularly when they have insufficient authority to direct how the sectors concerned actually go about their tasks. Heaver (2005) suggests that a better arrangement would be to allow the sectors the latitude and resources to carry out their own programs, with the nutrition coordination agency being granted the necessary authority to define overall policies and strategies and to guide the allocation of resources. Government should make use of the existing sectoral infrastructure to implement programs, however imperfect it may be, and build on what is already in place (Kennedy 1994). A lesson that seems to have been widely recognized, if not widely learned, is to "plan multi-sectorally, but implement sectorally" (Maxwell and Conway 2000).

As such, multisectoral coordination agencies have a place in the implementation of government strategies to sustainably reduce levels of undernu-

trition. With sufficient authority and resources, cross-sectoral coordination bodies can ensure that proper incentives—both positive and negative—are introduced to motivate sector institutions to prioritize activities and allocate resources targeting improved nutrition outcomes. Cross-sectoral nutrition coordination bodies can operate the accountability mechanisms needed to ensure that sector agencies carry out their mandated nutrition-related activities in alignment with broader government strategies to address malnutrition. Moreover, such agencies should be expected to continually engage in relevant national and sectoral policy processes, including in agriculture, to ensure that undernutrition continues to be viewed by political leaders and sector managers as a development priority (World Bank 2006a).

Cross-Sector Issues as Policy Priorities

In a normative sense, formal policies define in quite explicit terms what is considered the common good for the citizens of a nation and serve as statements of how government intends to prioritize its actions and its expenditures. Formal statements of policy are arguably more important for defining priorities when related to issues, such as nutrition issues, that fall outside of sector-specific interests. Whereas sector-specific mandates and worldviews serve to motivate action to address issues that fall within the competencies of a single sector, such incentives are absent for cross-sectoral issues. Making it clear that the priorities of government include mounting effective action to reduce undernutrition is one way in which sector priorities can be swayed toward paying closer attention to the needs of the undernourished. Public resource allocations to the agriculture sector may be made contingent on how much the sector has contributed and plans to contribute to the attainment of broader development objectives, such as those articulated in a master development plan or a Poverty Reduction Strategy. This can put in place stronger incentives for agriculturists to formulate work plans that go beyond their traditional narrow sectoral objectives. With that objective in mind, Ugandan nutritionists participated effectively in 2004 in revising the Poverty Eradication Action Plan, the government's master development strategy, resulting in heightened attention to undernutrition within this broader policy (Benson et al.

2004). However, follow-up research is needed to determine whether the increased emphasis on nutrition in this policy actually has led to increased attention to the problem of undernutrition in the annual work plans of the various state sectors in Uganda or in the allocation of resources to attain improved nutrition objectives.

For such high-level policy statements to influence sectoral efforts to address undernutrition, sustained interest by political leaders in attaining broad improved nutritional outcomes is required. Political champions for the attainment of improved nutrition are needed: individuals who are politically well connected, are persistent in character, and have access to many of the multiple arenas and institutional venues in which policy debates are undertaken. Such champions have been shown to be a key element in several instances in which significant changes were brought about in the priority given to state efforts to combat undernutrition (Rokx 2000). Similarly, international donors can provide important incentives by providing funding and capacity building opportunities to agencies in the agricultural sector or other sectors so that they can work toward reducing the numbers of the undernourished in a country or area. However, if implemented in a one-off fashion, the sustainability of such changes is open to question (Winikoff 1978). If attention to undernutrition enjoyed a high profile in national policy process or in donor priorities, subsequent changes in leadership of government or of donor organizations often result in a diminished profile for nutrition as a development objective. Continual strategic advocacy for nutrition action thus becomes an important element if agriculture and other sectors are to undertake actions at a level and for a length of time sufficient to bring about substantive reductions in the numbers of undernourished in the population.

Nutrition Objectives for Agricultural Activities

Activities with clear nutrition implications in the agricultural sector have been the focus of much of the technical content of this report. These include the production and consumption of staple food crops, fruits and vegetables, and animal products that are rich in micronutrients or otherwise contribute to a high-quality diet and the use of agricultural communication channels to

enhance nutritional knowledge within farming households. Although their success in contributing to improved nutritional outcomes varies depending on the pathways by which the desired nutritional effects are obtained, such activities do compel their implementers in the agricultural sector to undertake nutritional analyses to identify the nutritionally vulnerable in the population in which they work and to diagnose the causes of that malnutrition. Such analyses, if conducted in an informed manner, will highlight the important contribution that agricultural initiatives can make in assisting the undernourished, the need for complementary action on the part of other sectors, and the importance of improved nutrition as an input to a more productive agricultural sector. With sufficient political support, initial efforts by agriculturists to contribute to improved nutrition should increase in scope and complexity as the determinants of improved nutrition are increasingly made clear to those involved through practice. The nutrition objectives of agricultural activities can foster a more holistic vision of what is needed across the various public sectors to sustainably improve nutrition. However, progress in this regard is not assured, as the example in box 9 shows.

Community-Driven Development

Community-directed efforts also can provide important incentives for agriculturists to contribute to efforts to reduce undernutrition, often working in concert with other sectors. Community-driven development (CDD) gives control of many local development activities to those who will be most affected by them, the local residents (Dongier et al. 2003). When governments support such efforts, they usually also commit to contributing state resources and expertise to the community as its members work to realize their development ambitions. However, communities are unlikely to prioritize their development needs neatly according to unique sectoral competencies (Mason 2000). That being the case, community expectations that state agencies will help them address a problem requiring contributions from multiple sectors, such as undernutrition, provide important incentives for cross-sectoral action to be undertaken. In instances in which governments are strongly committed to supporting community-driven efforts, there may be sufficient incentives from community demands

Box 9 Home Economists as Agricultural Extension Agents

Progressive increased attention to nutrition within agriculture is not assured. Agricultural extension services offer a case in point. Such services provide a channel for reaching rural smallholder households with information on how they might provide better care to their nutritionally vulnerable members. In the 1970s and 1980s, recognizing this, many extension services in Sub-Saharan Africa, including Ghana and Uganda, included among their fieldworkers home economists, most of whom were women. Their function was primarily to work with women in farming households on both production and consumption issues, including nutrition. However, during the past 20 years, most extension services have been reorganized, including through programs of “professionalization,” whereby field extension agents had to meet minimum professional qualifications to be retained in the service. Because these qualifications were primarily agri-

cultural production-oriented, most home economists were eliminated from extension services.

Moreover, the service has also become more male dominated as a result. That is due to gender sorting in school, in which boys are more likely than girls to follow the natural sciences-focused course of study necessary to attain professional qualifications in agriculture. Several important determinants of nutritional status have strongly gendered characteristics, particularly breastfeeding, weaning, childcare, and meal preparation. Consequently, although information on such nutrition concerns may still feature among information that extension agents offer to farming households, male extension agents are a poor choice as messenger on these topics. We should expect that the level and quality of knowledge on nutrition obtained by farming households from extension agents certainly has not improved with the restructuring of extension services.

Source: Benson et al. 2004.

for cross-sectoral activities to flourish despite the bureaucratic organization of the sectors. For example, community nutrition programs that involve cross-sectoral teams from government agencies in providing community facilitation services have led to substantial reductions in undernutrition in several Asian countries (Tontisirin and Gillespie 1999).

Moreover, the local scale at which action will be taken by the agents of the various public sectors concerned also may enable such action to be performed more easily. The resource conflicts between sectors that were noted as constraining cross-sectoral undertakings typically play out at the national level in most countries. At more local levels, civil servants may have more limited control over how resource allocations are made across the sectors. However, the ability of local-level state agencies to work collaboratively in assisting communities will vary on a case-by-case basis. In both Ghana and Uganda, countries in which the decentralization of state functions has progressed to a greater extent than in most other

African countries, district-level agriculturists stated that local concerns were not necessarily more important than sectoral concerns in guiding their actions (Benson et al. 2004). These agriculturists were still subordinate to sectoral superiors, they operated with limited resources, and many of the incentives that motivated their individual efforts hampered rather than fostered cross-sectoral action to assist communities. Consequently, although community-driven development may promote increased attention from agriculturists to local nutrition problems, there is no guarantee that it will do so.

Nutrition in Agricultural Training

As was shown earlier in the review chapters, agriculture may provide important elements necessary for sustained improvements to nutritional status in specific contexts, particularly among farming populations. If improving nutrition is a high priority development objective of govern-

ment, attaining that objective will require a more sophisticated understanding of the determinants of improved nutrition by professionals in the public sectors concerned. Providing training in human nutrition to agriculturists is an important component of this objective. Whatever the sector or sectors, “the choice of the most appropriate intervention will depend on who is malnourished and why” (Kennedy 1994). Providing training in nutritional analysis will make it more likely that agricultural projects and programs that seek to improve the nutritional status of the target population will be based on a clear conceptual and analytical framework for the way the nutritional goals will be attained. Similarly, it will also allow for better identification and understanding of the needs of the undernourished that the agricultural sector can assist in meeting and enable better monitoring of project performance in meeting those needs. However, few countries, if any, now require that their agricultural trainees acquire a basic understanding of the determinants of improved nutrition.

CONCLUSIONS

The institutional barriers that agriculturists, particularly those in the public sector, face in trying to mount effective action to assist the undernourished are durable and strong. The fact that the organization of these institutions is relatively ineffective for addressing the problem of undernutrition in society is unlikely to be sufficiently compelling to cause these institutional structures or the manner in which they operate to change. Consequently, although strong action by the agricultural sector or broad coordinated action by several sectors may logically appear to be required to reduce levels of undernutrition, in practice an opportunistic approach may be more effective. Such a strategy would use existing individual activities in the agricultural sector and in other sectors in an instrumental way to address important context-specific determinants of undernutrition. Working in this incremental manner appears more likely to be successful than mounting a large-scale cross-sectoral effort that is a poor match for the institutional framework in which it would be implemented (Lynch 1979). Experience from many cross-sectoral efforts, focused on both nutrition and other prob-

lems, demonstrates that there is considerable merit in being task or problem oriented, starting small, achieving short-term goals, and building on these successes iteratively to address larger problems (Maxwell and Conway 2000).

Coordinated cross-sectoral efforts may be necessary to sustainably reduce undernutrition. However, given the past failure of such efforts, new initiatives should first be piloted before being scaled up, particularly in those institutional environments in which bureaucratic structures and processes are rigid. In such cases, “contrary to logical argument, the complex etiology of malnutrition does not necessarily demand a complex response” (Ross and Posanai, cited in Levinson 1995). Individual sectoral responses will often be the best that can be realistically expected. No nutrition program at the outset should depend on intersectoral coordination for its success. The risk that such coordination is not going to happen is too great (Levinson 1995). In instances in which cross-sectoral action is required, alternative partners to other sectors in the state bureaucracy, such as NGOs, may offer greater potential for success. However, simply ensuring that the agriculture sector, or, for that matter, any other sector with a role to play in improving nutrition, takes that role seriously is an important first step. Coordinated efforts should follow only once such commitments are clear.

Moreover, the causes of undernutrition are context specific. Agriculturists need to be clear about what they can contribute in resolving malnutrition in a particular context. Having this clear understanding not only guides program design, but it also enables agriculturists to evaluate whether means other than agriculture might be more efficient in attaining specific goals of nutritional improvement. There are likely to be significant opportunity costs associated with agriculturists devoting their energies to nutrition objectives (Pinstrup-Andersen 1982). These costs need to be evaluated. Consequently, capacity for nutrition analysis is critical to any planning by agriculturists to address aspects of the problem of undernutrition.

The undernourished can improve their nutritional status through agricultural means. There are many good reasons for providing incentives to agriculturists to address problems of undernutri-

tion in a dedicated manner. However, Levinson (1995) suggests that the reverse relationship is also important. “Increased agricultural production per se is insufficient if that production does not address hunger and malnutrition through its production or consumption effects.” Attention to the nutrition

benefits to which agriculture can contribute forces the sector to consider more rigorously who benefits from increased agricultural productivity and to change its priorities and activities where necessary in light of these considerations.

Lessons Learned and Next Steps

This report analyzes what has been learned about the way agricultural interventions influence nutrition outcomes in low- and middle-income countries. It synthesizes lessons from past institutional and organizational efforts and identifies developments in agriculture and nutrition that have transformed the context in which nutrition outcomes are affected by agriculture. Emerging from this analysis is the fact that agriculture carries real potential to contribute to improved nutritional outcomes. Agricultural programs should thus include nutrition as a specific objective and a clear plan of how to implement nutrition-sensitive agricultural interventions and how to achieve impact. The experience of agricultural programs that have done so points to a number of general lessons. The very inclusion of nutritional objectives by these programs reflects an implicit recognition that investing in agricultural production and growth does not necessarily result in improved nutrition. Nor do improved nutrition outcomes flow automatically from increased agricultural production, lower food prices, or higher incomes. Although these pathways may be instrumental in satisfying a number of necessary conditions for improved nutrition, they are not in themselves sufficient. The persistence of malnutrition despite the generally overwhelming success of food production belies any notion that the solution to adverse nutrition outcomes is attainable through the production side alone. Nutritional criteria have to be explicitly incorporated into the design of agricultural programs if nutritional objectives are embraced and if food production is to effectively answer the demand for foods with particular nutritional qualities. That represents both a challenge and an opportunity for agriculture and its major actors.

Incorporating nonagricultural criteria such as health and nutrition into the design and conduct of agricultural programs suggests developing an effective interface between agricultural and other institutions. Yet systematic high-level coordination between different sector ministries is challenging, given the bureaucratic barriers that divide them. The report therefore examined alternative approaches to formulating a more comprehensive approach to improving nutrition as a development objective. The prominence of nutrition as a policy priority in national development plans and poverty reduction strategies may provide a useful starting point. At this level, nutritional objectives transcend the administrative divisions between different government-sector institutions while still requiring their respective contributions.

Those institutions may find and capitalize on opportunities to work together, but their effective inputs should not be contingent on such active collaboration coming to pass. In this light, programs and policies can be planned multisectorally, yet be carried out sector by sector. Insofar as sector institutions are held accountable for their performance in achieving improved nutritional outcomes this accountability will provide them with incentives to explicitly address undernutrition within their respective mandates and work programs.

Sector ministries compete for limited government resources. If their budgetary allocations are made contingent on their contribution to reducing malnutrition as a national policy priority, their effectiveness in that role is more likely to become an institutional priority as well. Similarly, international donors can provide important incentives by offering funding and capacity building opportunities to agencies in the agricultural sector or other sectors so that they work toward reducing the numbers of undernourished in a country or area. To improve the chances of that happening, agricultural institutions should develop the internal capacity to analyze the nutritional implications of the programs they plan.

The context in which agricultural programs are implemented is shifting as agricultural and trade policies change, as new technologies are introduced, and as food marketing systems develop. These changes, which generally work to increase the market orientation of agriculture, affect the pathways linking agriculture to nutrition by altering the types and quality of the foods available in the marketplace, the price of food, the income of food producers, and the amount of food consumed from own-production. They are also affecting non-food factors that contribute to nutritional improvements, such as human capital. In addition, changing food consumption patterns affect the market demand that agricultural production seeks to satisfy. These changes present program planners with a moving target in tailoring programs to fit local realities. They also present practitioners and policy makers with new factors to consider as they seek to replicate successful experiences across localities and scale them up to provincial and national levels.

The empirical evidence presented in this report focused on agricultural programs and interventions carried out at the level of local communities. The most successful such projects were those that in-

vested broadly in improving human capital and that sustained and increased the livelihood assets of the poor. Below we summarize the key lessons learned about how these programs should be developed and implemented to help achieve improved nutritional outcomes. The recommendations should be implemented taking the changing context of agriculture and nutrition into account, and they should be accompanied by the investments in human capital and institutional changes needed for successful implementation.

Take local contexts into account. Designing programs to accommodate prevailing agricultural and nutritional conditions entails developing a sound understanding of producers' priorities, incentives, assets, vulnerabilities, and livelihood strategies. This is all too familiar to agricultural planners and can be said of virtually any agricultural intervention. The need to evaluate and target major nutritional problems experienced by the community in program design is less familiar, but is an essential requirement for any agricultural intervention that has nutrition-related objectives. Understanding the motives and constraints that affect household consumption decisions is in this sense no less important than understanding those that affect production decisions.

Many of these factors relate to household economics and to local perspectives of socioeconomic realities. Some, however, are attributable to cultural norms that in and of themselves have little if anything to do with economics—but that may bear heavily on the rationales behind households' economic decisions. They may determine outright which household members maintain control over which household resources and may influence nutritionally vital decisions such as the allocation of different quantities and types of food among household members. From that angle, women emerge as vitally important agents, both in their roles as producers and as custodians of household welfare. Their importance, moreover, generally increases in the lowest-income settings and among households with high dependency ratios—in which a large proportion of household members are nonearning and often nutritionally vulnerable dependents. Beginning with pilot programs and conscientiously employing evaluation criteria before going to scale can be a particularly effective way to ensure that local contexts are taken into account.

Enable and empower women. The resources and income flows that women control wield dispropor-

tionately positive impacts on household health and nutrition. In some parts of the world, women tend to lack access to economic opportunities outside the domestic sphere to which traditional customs often confine them, especially in rural areas. They are also very often severely constrained by time and the multiple—often simultaneous—roles they play as producers and caregivers. Agricultural programs and policies that empower and enable women and that involve them in decisions and activities throughout the life of the program achieve greater nutritional impacts. Such programs increase women's control over income and other productive resources like credit by targeting them in their roles as economic agents.

Incorporate nutrition outreach and behavior change. Using information services to change the behavior of producers in order to make them more productive or better able to respond to market signals is familiar to agricultural practitioners. Similar information services can be employed to change behavior among people in their roles as consumers and as decision makers within their households. Women's access to services can be as important to household nutrition as their access to income and productive assets. Access to health services is a natural priority, but even this access presupposes that people know when to avail themselves of such services. Information services can educate women both in their roles as economic agents and as typically the principal stewards of household nutrition, food security, and health. While women are by no means the sole intended audience of such knowledge, targeting women with health and nutrition information is likely to have even greater catalytic effect, given their typically closer affiliation with the household.

People who are armed with information and knowledge about the nutritional significance of the foods they produce and eat are able to make better production and consumption decisions. Health information services provide a potent means of changing behaviors to reduce the high levels of childhood morbidity that are associated with inappropriate feeding practices, premature weaning, and childcare generally. Providing households with health information about sanitary food preparation and water use and the prevention of infectious and food-borne diseases can dramatically improve nutrition outcomes—particularly with respect to those diarrheal illnesses that dispropor-

tionately afflict children and increase their risk of dying. Agricultural extension services and public information campaigns such as those dealing with integrated pest management are also important vehicles for conveying health-related information.

Nutrition-related education and communication strategies may offer instruction on food preparation and safety, child care and feeding practices, and the nutritional qualities of different foods. A woman armed with information that enables her to recognize the symptoms of a vitamin A deficiency and who has learned about key sources of this nutrient is better placed to make an appropriate dietary adjustment—especially when she has participated in an agricultural program involving a food source that can be applied to that nutrient deficiency. A woman equipped with knowledge that enables her to recognize a particular medical condition is likewise by definition better placed to treat it or to know when the affected family member should be taken to a health service provider.

Information is something that is required *from* households and communities as well as something to be made available to them. The subjective economic, social, and cultural reasons that underlie household production and consumption decisions are largely inaccessible to program personnel from outside the participating community. Indigenous knowledge and livelihood strategies are very often unspoken and may encompass local understanding of opportunities and risks that carry important practical merit for nutrition programming—merit that may very well not be obvious to the outside observer. In areas in which community-based, local civil society or nongovernmental organizations are active, they may represent important sources of information on local perspectives and present agricultural programs with valuable partnerships with which to engage local communities. Community-based organizations represent important reservoirs of social capital and are embedded in target communities in which community members make collective decisions about how local resources are to be used and how livelihoods are to be advanced. Other organizations that have operated for years in local communities are likely to have established relationships of intimate trust and rapport with families and individuals in local communities and are able to listen to local concerns and advise on possible resolutions. These can be conduits of two-way information flows between pro-

gram administrators and community members and are often well-situated to serve as agents in monitoring and evaluation. Local organizations, moreover, are often relatively free of the sectoral divisions of higher-level bureaucracies and may employ agriculturists and health and nutrition experts from local government agencies who are well aware of each other's activities, concerns, and priorities and, as such, can operate in a more effective and coordinated manner.

An additional lesson learned through the review is that *poor producers should be provided with help and support to respond to changing food consumption patterns*. Anticipating and responding to changing demand is a vital imperative for farmers in general, but among poor farmers in developing countries the stakes are particularly high. A significant part of their production is intended for their household's own consumption and therefore much of the demand they are satisfying is their own. With respect to the proportion of food they produce for market, the changing agricultural context has important implications for the prices they are paid for their products, and increasing demand for high-value food sources represents an important opportunity to earn more income. Yet switching to new and unfamiliar crops and producing for foreign markets with stringent food quality and safety requirements are also fraught with risk, and both opportunities and risks need to be addressed by agricultural programs.

Next Steps. There are a number of important issues not covered in this paper that deserve separate investigation and analysis. The effects of climate change and the implications of agricultural production shifting from food products to biofuels are matters of serious concern for food security, health, and nutrition. Analysis of their potential impacts on food production and prices suggests itself as an important object of future research.

The experience of past and ongoing agricultural interventions with nutrition-related objectives and the connections between agricultural production and nutrition more broadly, shed light on a number of variables and causal dynamics that agricultural practitioners should take into account when planning programs or providing policy advice. Focusing the crosshairs of production goals onto nutrition-related targets is something that agricultural planners are likely to be called upon to do more often, for there is good reason to anticipate that nutritional aims will come to play more prominently in the calculus by which the value of agricultural programs are rated. Future agricultural programs implemented with nutrition objectives will need to address the real challenge of going to scale and should be carefully monitored and rigorously evaluated to ensure that performance can be continually tracked and improved. It is hoped that the expository account offered in this report lays the groundwork for more practical work in which the details of applying these lessons operationally can be prescribed.

METHODOLOGY USED IN CHAPTER 3 (STAPLES)

The following searches were carried out for the purposes of the literature review.

- The most recently published review (Berti et al. 2004) employed a documented search strategy with search date of November 2001. We repeated their search to cover the years 2001–2007, with slight modifications to their search terms (below). We searched in PubMed and in Science Citation Index Expanded and Social Sciences Citation Index (latter two via Web of Science). This search was very broad and yielded approximately 1,700 items indexed in Medline and approximately 1,800 items indexed in Web of Science.
 - (agricult* OR “sustainable development” OR “rural development” OR “food production” OR farm*) AND (nutriti* OR anthropom* OR diet* OR “child growth”)
 - Search limits also excluded studies with animals as subjects; search date March 2007.
- In addition, to ensure that no relevant studies were missed, we supplemented with Medline searches using the following terms:
 - nutriti* AND agriculture AND (trial OR interve* OR effect* or effic* OR program OR policy)
 - “food security” AND agriculture AND (trial OR interve* OR effect* or effic* OR program OR policy)
 - These latter two searches yielded 105 items and overlapped with the broader searches.
- Third, we searched forward (Web of Science cited reference search) from three previous reviews (Kennedy et al. 1992; DeWalt 1993; Berti et al. 2004 and evaluated resulting studies for relevance.
- In addition, in February 2007, a number of websites were searched for project results papers, including the following:
 - Bioversity International (formerly the International Plant Genetic Research Institute and the International Network for the Improvement of Banana and Plantain): <http://www.bioversityinternational.org/>
 - Collaborative Crop Research Program: <http://mcknight.ccrp.cornell.edu/projects/nutrition.html>
 - Food and Agriculture Organization: <http://www.fao.org/documents/>
 - HarvestPlus Program: <http://www.harvestplus.org/>
 - Healthbridge Canada (formerly Programme for Appropriate Technology in Health, Canada): http://www.healthbridge.ca/foodandnutrition_e.cfm
 - International Center for Research on Women: <http://www.icrw.org/>
 - International Food Policy Research Institute: <http://www.ifpri.org/>
 - International Fund for Agricultural Development: <http://www.ifad.org/>
 - Michigan State University, Towards Sustainable Nutrition Improvement Project: <http://www.aec.msu.edu/fs2/tsni/index.htm>

METHODOLOGY USED IN CHAPTER 4 (FRUITS AND VEGETABLES)

Databases

A structured electronic search of the PubMed database was conducted. It included publications from 1980 to January 2007. Other limits included human studies in the following languages: English, French, Italian, and Spanish. Significant efforts were also made to identify other studies through searches in the “gray literature” by accessing relevant Web sites. In addition, a number of experts from various international organizations were contacted through e-mail to ask for copies of reports documenting their experiences. The obtained reports were included in this review. Additional publications were obtained by going through the references of the retained publications to identify those that were relevant for this topic. Finally, a number of articles and reports were obtained from colleagues who already had articles available that had been compiled for previous reviews.

Search Terms

After extensive testing, the following string of search terms proved the most effective in identifying the relevant literature:

(“Nutrition Disorders”[MeSH] OR
“Nutritional Status”[MeSH]) AND
(“Agriculture”[MeSH] OR Horticulture
OR Garden) AND (“Nutrition

Assessment”[MeSH] OR Dietary Guideline
OR School-based intervention OR Program
OR Intervention OR Promotion OR Policy
OR Nutrition Education OR Prevention OR
“Education”[MeSH] OR “Behavior”[MeSH]
OR “Marketing”[MeSH] OR Mass-media
OR “Schools”[MeSH] OR
“Communication”[MeSH] OR “Intervention
Studies”[MeSH] OR “Public Policy”[MeSH]
OR “Randomized Controlled Trials”[MeSH]
OR “Health Education”[MeSH] OR
“Government Programs”[MeSH] OR
“National Health Programs”[MeSH] OR
“Health Promotion”[MeSH] OR “Nutrition
Policy”[MeSH] OR “prevention and control”
[Subheading] OR “Guidelines”[MeSH]
OR Impact OR Efficacy OR Effectiv*

Inclusion/exclusion criteria: Only high-quality studies were included, that is, those that had an experimental or quasi-experimental design for which the intervention was clearly described and that included tests of statistical significance in the impact analysis.

Searches

The PubMed search using the search string listed above resulted in a total of 188 articles. All were subjected to a title and abstract scan for relevance, and a total of 72 were found to be relevant. They were evaluated in more detail, and a total of 26 of these articles were obtained in full-paper form for inclusion in this document. Several of these papers were background or historic documents that did not report on a specific intervention.

Bibliography

- Adamson, P. 2004. "Vitamin and Mineral Deficiency: A Global Progress Report." The Micronutrient Initiative and UNICEF.
- Adato, M., and R. Meinzen-Dick. 2007. *Agricultural Research, Livelihoods, and Poverty. Studies of Economic and Social Impacts in Six Countries*. Baltimore, MD: The Johns Hopkins University Press for IFPRI (International Food Policy Research Institute).
- Ahmad, M., C. Cororaton, A. Qayyum, M. Iqbal, and P. Dorosh. 2006. "Impact of Domestic Policies towards Agricultural Trade Liberalization and Market Reform on Food Security in Pakistan." IFPRI (International Food Policy Research Institute), Washington, DC (photocopy).
- Ahmed, M. M., M. Jabbar, and S. Ehui. 2000. "Household-Level Economic and Nutritional Level Impacts of Market-Oriented Dairy Production in the Ethiopian Highlands." *Food and Nutrition Bulletin* 21 (4): 460–65.
- Alderman, H. 1987. "Cooperative Dairy Development in Karnataka, India: An Assessment." Research Report 64. IFPRI (International Food Policy Research Institute), Washington, DC.
- Alderman, J., J. Hoddinott, L. Haddad, and C. Udry. 1995. "Gender Differentials in Farm Productivity: Implications for Household Efficiency and Agricultural Policy." IFPRI (International Food Policy Research Institute), Washington, DC.
- Allen, L. 2003. "Animal Source Foods to Improve Micronutrient Nutrition and Human Function in Developing Countries." *Journal of Nutrition* 133: 3875S–78S.
- Allen, L., and S. Gillespie. 2001. *What Works? A Review of the Efficacy and Effectiveness of Nutrition Interventions*. Geneva: United Nations Administrative Committee on Coordination, Sub-Committee on Nutrition, in collaboration with the Asian Development Bank.
- Aphane, J., M.L. Chadha, and M.O. Oluoch. 2003. "Increasing the Consumption of Micronutrient-rich Foods through Production and Promotion of Indigenous Foods." AVRDC (Asian Vegetable Research and Development Center)—The World Vegetable Center. Tainan, Taiwan.
- Athukorala, P., and D. Sen. 1998. "Processed Food Exports form Developing Countries: Patterns and Determinants." *Food Policy* 23 (1): 41–54.
- Attig, G. A., S. Simtasiri, K. Ittikom, and S. Dahanamitta. 1993. "Promoting Homestead Gardening to Control Vitamin A Deficiency in North-Eastern Thailand." *Food, Nutrition and Agriculture* 7: 1825.
- Ayalew, W., Z. W. Gebriel, and H. Kassa. 1999a. "Reducing Vitamin A Deficiency in Ethiopia: Linkages with a Women-Focused Dairy Goat Farming Project." Research Report No. 4. Center for Research on Women (ICRW)/Opportunities for Micronutrient Interventions (OMNI), Washington, DC.
- Ayalew, W., Z. W. Gebriel, and H. Kassa. 1999b. "Improving Vitamin A Intake through a Woman-Focused Dairy Goat Development Project in Ethiopia." Research Report Series No. 4. ICRW/OMNI (International Center for Research on Women/Opportunities for Micronutrient Interventions), Washington, DC.
- Badiane, O. 2000. "The Effects of Liberalization on Food Markets in Africa." In *Agricultural Markets Beyond Liberalization*, ed. A. van Tilburg, H. A. J. Moll, and A. Kuyvenhoven. Dordrecht: Kluwer Academic Publishers.
- Baenzinger, P. S., W. K. Russell, G. L. Graef, and B. T. Campbell. 2006. "Improving Lives: 50 Years of Crop Breeding, Genetics, and Cytology." *Crop Science* 46: 2230–44.
- Banerjee, A. V., and E. Duflo. 2006. "The Economic Lives of the Poor." MIT Department of Economics Working Paper No. 06-29. SSRN: <http://ssrn.com/abstract=942062>.
- Barghouti, S., S. Kane, K. Sorby, and M. Ali. 2004. "Agricultural Diversification for the Poor: Guidelines for Practitioners." Agriculture and Rural Development Discussion Paper 1. World Bank, Washington, DC.
- Bazzano, L. A. 2004. "Dietary Intake of Fruits and Vegetables and Dietary Risk of Diabetes Mellitus and Cardiovascular Diseases (CVD)." Background Document 4-b. Prepared for the Joint FAO/WHO Workshop on Fruit and Vegetables for Health, Kobe, Japan, September 1–3, 2004.
- Begum, J. M. 1994. The Impact of Dairy Development on Protein and Calorie Intake of Pre-School Children. *Indian J Med Science* 48 (3): 61–64.
- Bell, A. C., K. Ge, and B. M. Popkin. 2002. "The Road to Obesity or the Path to Prevention: Motorized Transportation and Obesity in China." *Obesity Research* 10 (4): 277–83.
- Bell, A. C., K. Ge, and B. M. Popkin. 2001. "Weight Gain and Its Predictors in Chinese Adults." *International Journal of Obesity and Related Metabolic Disorders* 25 (7): 1079–86.
- Benson, T. Forthcoming. "Cross-Sectoral Coordination Failure: How Significant a Constraint in National Efforts to Tackle Malnutrition in Africa?" *Food and Nutrition Bulletin*.
- Benson, T., T. Palmer, R. Satcher, and C. Johnson-Welch. 2004. *Crossing Boundaries to Reduce Malnutrition? An Institutional Study of Agriculture and Nutrition in Uganda, Mozambique, Nigeria, and Ghana*. Washington, DC: International Food Policy Research Institute.
- Berti, P. R., J. Krasevec, and S. FitzGerald. 2004. "A Review of the Effectiveness of Agriculture Interventions in Improving Nutrition Outcomes." *Public Health Nutrition* 7 (5): 599–609.
- Bhagwati, J. N. 1993. *India in Transition: Freeing the Economy*. Oxford: Clarendon Press.
- Bhat, R. V., and S. Vasanthi. 1999. "Mycotoxin Contamination of Foods and Feeds." Working document of the Third Joint FAO/WHO/UNEP International Conference on Mycotoxins. MYC-CONF/99/4a, Tunis, Tunisia.
- Binswanger, H. P., and J. von Braun. 1991. "Technological Change and Commercialization in Agriculture: The Effect on the Poor." *World Bank Research Observer* 6 (1): 57–80.
- Birthal, P. S., P. K. Joshi, and A. Gulati. 2006. "Vertical Coordination in High-Value Food Commodities: Implications for Smallholders." Draft Research Report. IFPRI (International Food Policy Research Institute), Washington, DC.

- Blanken, J., J. von Braun, and H. de Haen. 1994. "The Triple Role of Potatoes as a Source of Cash, Food, and Employment: Effects on Nutritional Improvement in Rwanda." In *Agricultural Commercialization, Economic Development, and Nutrition*, ed. J. von Braun and E. Kennedy, 276–94. Baltimore, MD: Johns Hopkins University Press.
- Block, S. 2003. "Nutrition Knowledge, Household Coping, and the Demand for Micronutrient Rich Foods." Nutrition Working Paper 5, BAPPENAS/Department Pertanian/USAID/DAI Food Policy Advisory team.
- Boselie, D., S. Henson and D. Weatherspoon. 2003. "Supermarket Procurement Practices in Developing Countries: Redefining the Roles of the Public and Private Sectors." *American Journal of Agricultural Economics* 85 (5): 1155–61.
- Bouis, H. 1997. "The Determinants of Demand for Micronutrients: An Analysis of Rural Households in Bangladesh." FCND (Food Consumption and Nutrition Division of IFPRI) Discussion Paper No. 32. IFPRI (International Food Policy Research Institute), Washington, DC.
- Bouis, H. 1999. "Economics of Enhanced Micronutrient Density in Food Staples." *Field Crops Research* 60 (1-2) 165–173.
- Bouis, H. 2000b. "Improving Nutrition through Agriculture: The Role of International Agricultural Research." *Food and Nutrition Bulletin* 21 (4) 550–566.
- Bouis, H. 2002a. "Three Criteria for Establishing the Usefulness of Biotechnology for Reducing Micronutrient Malnutrition." *Food and Nutrition Bulletin* 23 (4) 351–53.
- Bouis, H. 2002b. "Plant Breeding: A New Tool for Fighting Micronutrient Malnutrition." *Journal of Nutrition* 132: 491S–94S.
- Bouis, H., and J. Hunt. 1999. "Linking Food and Nutrition Security: Past Lessons and Future Opportunities." *Asian Development Review* 17: 168–213.
- Bouis, H., B. de la Briere, L. Guitierrez, K. Hallman, N. Hassan, O. Hels, W. Quabili, A. Quisumbing, S. Thilsted, Z. Zihad, and S. Zohir. 1998. *Commercial Vegetable and Polyculture Fish Production in Bangladesh: Their Impacts on Income, Household Resource Allocation, and Nutrition*. Washington, DC: International Food Policy Research Institute.
- Brouwers, T. 2006. "India: Dairy Giant Walking Barefoot." *ZuivelZicht Special India*, February 2006. Uitgeverij, Netherlands.
- Brugere, C., K. McAndrew, and P. Bulcock. 2001. "Does Cage Aquaculture Address Gender Goals in Development? Results of a Case Study in Bangladesh." *Aquaculture Economics and Management* 5 (3–4): 179–89.
- Bruinsma, J. 2003. *World Agriculture: Towards 2015/2030: An FAO Perspective*. London: Earthscan.
- Brun, T. A., C. Geissler, and E. Kennedy. 1991. "The Impact of Agricultural Projects on Food, Nutrition and Health." *World Review of Nutrition and Dietetics* 65: 99–123.
- Brun, T., J. Reynaud, and S. Chevassus-Agnes. 1989. "Food and Nutrition Impact of One Homestead Garden Project in Senegal." *Ecology of Food and Nutrition* 23: 91.
- Brun, T. A., C. Geissler, and E. Kennedy. 1991. The Impact of Agricultural Projects on Food, Nutrition and Health. *World Review of Nutrition and Dietetics* 65: 99–123.
- Bushamuka, V. N., S. de Pee, A. Talukder, L. Kiess, D. Panagides, A. Taher, and M. Bloem. 2005. "Impact of a Homestead Gardening Program on Household Food Security and Empowerment of Women in Bangladesh." *Food and Nutrition Bulletin* 26 (1): 17–25.
- Calvin, L. 2003. "Produce, Food Safety, and International Trade: Response to U.S. Foodborne Illness Outbreaks Associated with Imported Produce." In *International Trade and Food Safety: Economic Theory and Case Studies*, ed. J. Buzby. USDA, Econ. Res. Serv., AER-828.
- CARE. 1995. "A Study on Evaluation of Homestead Gardening Program in Bajura and Mahottari Districts." Katmandu, Nepal.
- Carrasco Sanz, N. C., R. M. D. deUbillas, I. S. Guillén, and S. M. Ferreira. 1998. "Increasing Women's Involvement in Community Decision-Making: A Means to Improve Iron Status." Research Report No. 1. ICRW/OMNI (International Center for Research on Women/Opportunities for Micronutrient Interventions), Washington, DC.
- Chakravarty, I. 2000. "Food-Based Strategies to Control Vitamin A Deficiency." *Food and Nutrition Bulletin* 21 (2): 135–43.
- Chen, K. Z., A. W. Shepherd, and C. da Silva. 2005. *Changes in Food Retailing in Asia: Fruit and Vegetable Supply Chain Developments and Implications for Farmers and Traditional Marketing Systems*. Rome: Food and Agriculture Organization of the United Nations.
- Chengappa, P. G., L. Achoth, A. Mukherjee, B. M. Reddy, and P. C. Ravi. Forthcoming. *Evolution of Food Retail Chains in India*. Washington, DC: International Food Policy Research Institute.
- Chowdhury N., N. Farid, and D. Roy. 2006. "Food Policy Liberalization in Bangladesh: How the Governments and the Markets Delivered?" MTID (Markets, Trade, and Institutions Division of IFPRI) Discussion Paper No. 92. IFPRI (International Food Policy Research Institute), Washington, DC.
- Chowdhury, S., A. Gulati, and E. Gumbira-Sa'id. 2005. "High Value Products, Supermarkets and Vertical Arrangements in Indonesia." MTID (Markets, Trade, and Institutions Division of IFPRI) Discussion Paper No. 83. IFPRI (International Food Policy Research Institute), Washington, DC.
- Christensen, C., and L. Witucki. 1982. "Food Problems and Emerging Policy Responses in Sub-Saharan Africa." *American Journal of Agricultural Economics* 64 (5) 889–896.
- de Pee, S., M. W. Bloem, R. Satoto, A. Yip, R. Sukaton, R. Tjong, R. Shrimpton, D. Muhilal, and B. Kodyat. 1998. "Impact of a Social Marketing Campaign Promoting Dark-Green Leafy Vegetables and Eggs in Central Java, Indonesia." *International Journal of Vitamin A Nutrition Research* 68: 389–398.
- de Pee, S., C. E. West, D. Muhilal, D. Karyadi, and J. G. Hautvast. 1995. "Lack of Improvement in Vitamin A Status with Increased Consumption of Dark-Green Leafy Vegetables." *Lancet* 346: 7581.
- DeGrassi, A. 2003. *Genetically Modified Crops and Sustainable Poverty Alleviation in Sub-Saharan Africa: An Assessment of Current Evidence*. Accra, Ghana: Third World Network—Africa.
- Delgado, C. L. 1995. "Africa's Changing Agricultural Development Strategies: Past and Present Paradigms as a Guide to the Future." IFPRI Food, Agriculture, and the Environment Discussion Paper 3. IFPRI (International Food Policy Research Institute), Washington, DC.
- Delgado, C. L., N. Minot, and M. Tiongo. 2005. "Evidence and Implications of Non-Tradability of Food Staples in Tanzania 1983–1998." *Journal of Development Studies* 41 (3): 376–93.
- Delgado, C., M. Rosegrant, H. Steinfeld, S. Ehui, and C. Courbois. 1999. *Livestock to 2020: The Next Food Revolution*. Washington, DC: IFPRI (International Food Policy Research Institute), and Rome: United Nations Food and Agricultural Organization.
- Deshingkar, P., C. Johnson, and J. Farrington. 2003. "State Transfers to the Poor and Back: The Case of Food for Work in India." *World Development* 33 (4) 575–591.
- Dessie, T., and B. Ogle. 2001. "Village Poultry Production Systems in the Central Highlands of Ethiopia." *Tropical Animal Health and Production* 33 (6): 521–37.

- DeWalt, K. 1993. "Nutrition and the Commercialization of Agriculture: Ten Years Later." *Social Science and Medicine* 36: 1407–16.
- DeWalt, K., B. DeWalt, J. Escudero, and D. Barkin. 1990. "Shifts from Maize to Sorghum Production: Nutrition Effects in Four Mexican Communities." *Food Policy* 15: 395–407.
- Dewey, K. G. 1981. "Nutritional Consequences of the Transformation from Subsistence to Commercial Agriculture in Tabasco, Mexico." *Human Ecology* 9 (2): 151–87.
- Dey, J. 1981. "Gambian Women: Unequal Partners in Rice Development Projects." *Journal of Development Studies* 17 (3).
- Diao, X., J. Rattsø, and H.E. Stokke. 2005. "International Spillovers, Productivity Growth and Openness in Thailand: An Intertemporal General Equilibrium Analysis." *Journal of Development Economics* 76 (2).
- Digal, L. N., and S. B. Concepcion. 2004. "Securing Small Producer Participation in Restructured National and Regional Agri-Food Systems—The Case of Philippines." http://regoverningmarkets.org/docs/Philippines_Report%20_6Nov2004.pdf.
- Dong, F., and H. Jensen. 2004. "The Challenge of Conforming to Sanitary and Phytosanitary Measures for China's Agricultural Exports." MATRIC Working Paper 04MWP-8. Midwest Agribusiness Trade Research and Information Center, Iowa State University, Ames, IA.
- Dongier, P., J. van Domelen, E. Ostrom, A. Ryan, W. Wakeman, A. Bebbington, S. Alkire, T. Esmail, and M. Polski. 2003. "Community Driven Development." In *A Sourcebook for Poverty Reduction Strategies*, ed. J. Klugman, 301–32. Washington, DC: World Bank.
- Dorjee, T., W. Roder, and L. Tshering. 2002. "Genetic Diversity of Bhutanese Yak (*Bos Grunniens*) Using Microsatellite Markers." *Proceedings of the Third International Congress on Yak*, Lhasa, China, September 4–9, 2000, pp. 197–201. Nairobi, Kenya: ILRI (International Livestock Research Institute).
- English, R., and J. Badcock. 1998. "A Community Nutrition Project in Viet Nam: Effects on Child Morbidity." *Food, Nutrition and Agriculture* 22: 15–21.
- English, R. M., J. Badcock, T. Giay, T. Ngu, A. M. Waters, and S. A. Bennett. 1997. "Effect of Nutrition Improvement Project on Morbidity from Infectious Diseases in Preschool Children in Vietnam: Comparison with Control Commune." *British Medical Journal* 315 (7116): 1122–25.
- Evenson, R. E., and D. Gollin. 2003. "The Green Revolution: An End of Century Perspective." *Science* 300 (5620) (May 2): 758–62.
- Evenson, R. E., and D. Gollin. 2003a. "Assessing the Impact of the Green Revolution: 1960 to 2000." *Science* 300: 758–62.
- Evenson, R. E., and D. Gollin. 2003b. *Crop Variety Improvement and Its Effect on Productivity: The Impact of International Agricultural Research*. Wallingford, U.K.: CAB International.
- Excerpt from invited comments during plenary session before break-out groups by Milla McLachlan. 2000. World Bank. *Food and Nutrition Bulletin* 21 (4): 560–61.
- Faber, M., and A. J. S. Benade. 2003. "Integrated Home-Gardening and Community-Based Growth Monitoring Activities to Alleviate Vitamin A Deficiency in a Rural Village in South Africa." *Food, Nutrition and Agriculture* 32: 24–32.
- Faber, M., A.B. Spinnler, and S.L. Venter. 2002a. "Increased Vitamin A Intake in Children Aged 2–5 Years through Targeted Home-Gardens in a Rural South African Community." *Public Health Nutrition* 5 (1): 11–16.
- Faber, M., M.A.S. Phungula, S. Venter, M.A. Dhansay, A.J. Spinnler. 2002b. "Homestead Gardens Focusing on the Production of Yellow and Dark-Green Leafy Vegetables Increase the Serum Retinol Concentrations of 2–5-Year-Old Children in South Africa." *American Journal of Clinical Nutrition* 76: 1048–54.
- Faiguenbaum, S., J. Berdegue, and T. Reardon. 2002. "The Rapid Rise of Supermarkets in Chile: Effects on Dairy, Vegetable, and Beef Chains." *Development Policy Review* 20 (4): 459–71.
- FAO (Food and Agriculture Organization of the United Nations). 2005. *FAOStat*. Rome, Italy, FAO.
- . 1996. *Rome Declaration on World Food Security*. World Food Summit 13–17 November 1996: A Manual. Rome, Italy: FAO.
- . 1982. *Integrating Nutrition into Agricultural and Rural Development Projects: A Manual*. FAO, Rome, Italy.
- . 2003. "The Role of Aquaculture in Improving Food Security and Nutrition." Report to Committee on World Food Security, 29th Session, May 12–16, 2003. FAO, Rome, Italy.
- . 2004. *The State of Agricultural Commodity Markets* 2004. FAO, Rome, Italy.
- . 2006. *The State of Food Insecurity in the World* 2006. FAO, Rome, Italy.
- . 2006a. *The State of the World Fisheries and Aquaculture*. FAO, Rome, Italy.
- Farina, E. M. M. Q. 2002. "Consolidation, Multinationalisation, and Competition in Brazil: Impacts on Horticulture and Dairy Products Systems." *Development Policy Review* 20 (4): 44157.
- Fleuret, P., and A. Fleuret. 1980. "Nutrition, Consumption, and Agricultural Change." *Human Organization* 39: 250–60.
- Galal, O. M., G. G. Harrison, A. I. Abdou, and A. Zein el Abedin. 1987. "The Impact of a Small-Scale Agricultural Intervention on Socio-Economic and Health Status." *Food Nutrition* 13 (1): 35–43.
- Gale, F., and B. Gilmour. 2002. "A Mature Retail Sector: Wider Channels for Food Imports?" In *China's Food and Agriculture: Issues for the 21st Century*, ed. F. Gale, F. Tuan, B. Lohmar, Hsin-Hui Hsu, and B. Gilmour. Agriculture Information Bulletin No. 775. Washington, DC: Economic Research Service, U.S. Department of Agriculture.
- Gehlhar, M., and A. Regmi. 2005. "Factors Shaping Global Food Markets." In *New Directions in Global Food Markets*, ed. A. Regmi and M. Gehlhar. Agriculture Information Bulletin No. 794. Washington, DC: Economic Research Service, U.S. Department of Agriculture.
- Ghezan, G., M. Mateos, and L. Viteri. 2002. "Impacts of Supermarkets and Fast-Food Chains on Horticulture Supply Chains in Argentina." *Development Policy Review* 20 (4): 389–408.
- Gibson, R. S. 1994. "Content and Bioavailability of Trace Elements in Vegetarian Diets." *American Journal of Clinical Nutrition* 59 (5 Suppl): 1223S–32S.
- Gillespie, S. 2001. "Strengthening Capacity to Improve Nutrition." Food Consumption and Nutrition Division Discussion Paper 106. IFPRI (International Food Policy Research Institute), Washington, DC.
- Gillespie, S., and J. Mason. 1994. "Controlling Vitamin A Deficiency." ACC/SCN State-of-the-Arts series. Nutrition Policy Discussion Paper No. 14. United Nations Administrative Committee on Coordination-Subcommittee on Nutrition, Geneva, Switzerland.
- Gittelsohn, J., and A. E. Vastine. 2003. "Sociocultural and Household Factors Impacting on the Selection, Allocation and Consumption of Animal Source Foods: Current Knowledge and Application." *Journal of Nutrition* 133 (11 Suppl 2): 4036S–41S.

- Goletti, F. 1999. "Agricultural Diversification and Rural Industrialization as a Strategy for Rural Income Growth and Poverty Reduction in Indochina and Myanmar." Markets and Structural Studies Division Discussion Paper No. 30. IFPRI (International Food Policy Research Institute), Washington, DC.
- Graham, R., R. Welch, D. Saunders, I. Ortiz-Monasterio, H. Bouis, M. Bonierbale, S. de Haan, G. Burgos, G. Thiele, R. Liria, C. Meisner, S. Beebe, M. Potts, M. Kadian, P. Hobbs, R. Gupta, and S. Twomlow. 2007. "Nutritious Subsistence Food Systems." *Advances in Agronomy* 92: 1–74.
- Greiner, T., and S. N. Mitra. 1995. "Evaluation of the Impact of a Food-Based Approach to Solving Vitamin A Deficiency in Bangladesh." *Food and Nutrition Bulletin* 16 (3): 193–205.
- Gueye, E. H. 2000. "Women and Family Poultry Production in Rural Africa." *Development in Practice* 10 (1): 98102.
- Habtemariam, K., W. Ayalew, G. Z. Habte, and M. T. Gebre. 2003. "Enhancing the Role of Livestock Production in Improving Nutritional Status of Farming Families: Lessons from a Dairy Goat Development Project in Eastern Ethiopia." *Livestock Research for Rural Development* 15 (6).
- Haddad, L., H. Alderman, S. Appleton, L. Song, Y. Yohannes. 2003. "Reducing Malnutrition: How Far does Income Growth Take Us?" *World Bank Economic Review* 17 (1).
- Haddad, L. and J. Hoddinott. 1994. "Women's Income and Boy-Girl Anthropometric Status in Cote d'Ivoire." *World Development* 22 (4).
- Haddad, L., S. Bhattarai, M. Immink, S. Kuman, and A. Slack. 1995. "More Than Food Is Needed to Achieve Good Nutrition by 2020." 2020 Vision Brief 25. IFPRI (International Food Policy and Research Institute), Washington, DC.
- Haddad, L., J. Hoddinott, and H. Alderman, eds. 1997. *Intrahousehold Resource Allocation in Developing Countries: Models, Methods, and Policy*. Baltimore, MD: Johns Hopkins University Press.
- Haddad, L., and L. C. Smith. 1999. "Explaining Child Malnutrition in Developing Countries: A Cross-Country Analysis." Discussion Paper 60. IFPRI (International Food Policy and Research Institute), Washington, DC.
- Hagenimana, V., M. Anyango Oyunga, J. Low, S. M. Nojoroge, S. T. Gichuki, and J. Kabira. 1999. "Testing the Effects of Women Farmers' Adoption and Production of Orange-Fleshed Sweet Potatoes on Dietary Vitamin A Intake in Kenya." Research Report No. 3. ICRW (International Center for Research on Women), Washington, DC; OMNI (Opportunities for Micronutrient Interventions).
- Hagenimana, V., J. Low, M. Anyango, K. Kurz, S. T. Gichuki, and J. Kabira. 2001. "Enhancing Vitamin A Intake in Young Children in Western Kenya: Orange-Fleshed Sweet Potatoes and Women Farmers Can Serve as Key Entry Points." *Food and Nutrition Bulletin* 22: 370–87.
- Hastings, G., M. Stead, L. McDermott, A. Forsyth, A. M. MacKintosh, M. Rayner, C. Godfrey, M. Caraher, and K. Angus. 2003. *Does Food Promotion Influence Children? A Systematic Review of the Evidence*. London: Food Standards Agency.
- Hawkes, C. 2002. "Marketing Activities of Global Soft Drink and Fast Food Companies in Emerging Markets: A Review." In *Globalization, Diets and Non-communicable Diseases*. Geneva, Switzerland: World Health Organization.
- Hawkes, C. 2006. "Uneven Dietary Development: Linking the Policies and Processes of Globalization with the Nutrition Transition, Obesity and Diet-Related Chronic Diseases." *Globalization and Health* 2: 4. <http://www.globalizationand-health.com/content/2/1/>.
- Hawkes, C. 2007a. "Agricultural and Food Policy for Cardiovascular Health in Latin America. Prevention and Control." *Journal of the World Heart Federation* 2: 137–47.
- Hawkes, C. 2007b. "Promoting Healthy Diets and Tackling Obesity and Diet-Related Chronic Diseases: What are the Agricultural Policy Levers?" *Food and Nutrition Bulletin* 28: S312–22.
- Hawkes, C., and M. Ruel. 2006a. *Understanding the Links between Agriculture and Health*. Washington, DC: IFPRI (International Food Policy Research Institute).
- Hawkes, C., and M. Ruel. 2006b. "Agriculture and Nutrition Linkages: Old Lessons and New Paradigms." In *Understanding the Links between Agriculture and Health*, ed. C. Hawkes and M. Ruel. Number 4. Washington, DC: IFPRI (International Food Policy Research Institute).
- Hawkes, C., M. Ruel, and S. Babu, eds. 2007. "Linkages between Agriculture and Health in Science, Policy, and Practice." *Food and Nutrition Bulletin* 20 (2) (Supplement).
- Hazell, P. B. R. 1987. Changing Pattern of Variability in Cereal Prices and Production. In *Agricultural Price Policy for Developing Countries*, ed. J. W. Mellor and R. Ahmed, 27–52. Baltimore, MD: Johns Hopkins University Press.
- Heaver, R. 2005. *Strengthening Country Commitment to Human Development—Lessons from Nutrition*. Washington, DC: World Bank.
- Henson, S. 2003. "The Economics of Food Safety in Developing Countries." ESA Working Paper No. 03-19. FAO, Rome, Italy.
- HKI (Helen Keller International). 2006. "Homestead Food Production for Improving Micronutrient Status of Women and Children, Poverty Reduction and Promotion of Gender Equality." Submitted to Novib. HKI, NY.
- . 2004. "Homestead Food Production Program in Central and Far-Western Nepal Increases Food and Nutrition Security." *Nutrition Bulletin* 2 (1).
- . 2004a. "Improving Household Food Security in Cambodia through Integration of Poultry Production into Existing Home Gardening Programs." *Cambodia Nutrition Bulletin* 4 (1).
- . 2003. *Integration of Animal Husbandry into Home Gardening Programs to Increase Vitamin A Intake from Foods: Bangladesh, Cambodia, and Nepal*. Asia Pacific Special Issue.
- HKI/AVRDC (Helen Keller International/Asian Vegetable Research and Development Center) (Taiwan). 1993. *Homestead Gardening in Bangladesh: Evaluation Report of the Homestead Gardening Pilot Project*. NY: HKI.
- HKI (Helen Keller International)/Asia-Pacific. 2001. *Homestead Food Production—A Strategy to Combat Malnutrition and Poverty*. Jakarta, Indonesia: HKI.
- HKI (Helen Keller International)/Cambodia. 2003. *Handbook for Homestead Gardening in Cambodia: The Complete Manual for Vegetable and Fruit Production*. Phnom Penh, Cambodia: Helen Keller Worldwide.
- Hoddinott, J., and L. Haddad. 1994. Women's Income and Boy-Girl Anthropometric Status in the Côte d'Ivoire. *World Development* 22 (4): 543–53. http://www.actahort.org/books/712/712_100.htm.
- Hu, D., T. Reardon, S. Rozelle, P. Timmer, and H. Wang. 2004. "The Emergence of Supermarkets with Chinese Characteristics: Challenges and Opportunities for China's Agricultural Development." *Development Policy Review* 22 (4) (September): 557–86.
- Humphrey, J. 2005. "Shaping Value Chains for Development: Global Value Chains in Agribusiness." Study commissioned by the Federal Ministry of Economic Cooperation and Development, Germany.

- Hussein, K. 2002. *Livelihoods Approaches Compared: A Multi-Agency Review of Current Practice*. London: Overseas Development Institute.
- IFAD (International Fund for Agricultural Development.) 2004. *Livestock Services and the Poor: A Global Initiative: Collecting, Coordinating and Sharing Experiences*. Rome, Italy: IFAD.
- IFPRI (International Food Policy Research Institute), Bangladesh Institute of Development Studies, Institute of Nutrition and Science, Data Analysis and Technical Assistance and Research Department of Human Nutrition, Royal Veterinary Agricultural University. 1998. *Commercial Vegetable and Polyculture Fish Production in Bangladesh: Their Impacts on Income, Household Resource Allocation, and Nutrition*, Vol. 1. Washington, DC: IFPRI.
- ILSI. (International Life Sciences Institute.) 2002. "Third-World Nutrition Programs: Closer Collaboration between Agriculture and Nutrition Scientists." *ILSI News* 20 (1): 1–8.
- James, W. P. T., R. Jackson-Leach, C. M. Ni, E. Kalamara, and M. Shayeghi. 2004. "Overweight and Obesity (high body mass index)." In *Comparative Quantification of Health Risks: Global and Regional Burden of Disease Attributable to Selected Major Risk Factors*, ed. M. Ezzati, A. Lopez, A. Rodgers, and C. J. L. Murray, 959–1108. World Health Organization, Geneva, Switzerland.
- Jha, S., and P. V. Srinivasan. 2004. "Achieving Food Security in a Cost-Effective Way." MTID Discussion Paper 67. IFPRI, Washington, DC.
- Johns, T., and B. R. Sthapit. 2004. "Biocultural Diversity in the Sustainability of Developing Country Food Systems." *Food and Nutrition Bulletin* 25: 143–55.
- Johns, T., I. Smith, and P. Eyzaguirre. 2006. "Understanding the Links between Agriculture, Nutrition, and Health: Agrobiodiversity, Nutrition, and Health." Focus Brief #13. IFPRI, Washington, DC.
- Johnson-Welch, C. 2002. *Linking Agriculture and Nutrition: The Human Dimension*. Washington, DC: International Center for Research on Women.
- Johnson-Welch, C., K. MacQuarrie, and S. Bunch. 2005. *A Leadership Strategy for Reducing Hunger and Malnutrition in Africa: The Agriculture-Nutrition Advantage*. Washington, D.C.: International Center for Research on Women.
- Kapinga, R., A. Anderson, C. Crissman, D. Zhang, B. Lemaga, and F. Opio. 2005. "Vitamin A Partnership for Africa: A Food Based Approach to Combat Vitamin A Deficiency in Sub-Saharan Africa through Increased Utilization of Orange-Fleshed Sweetpotato." *Chronica Horticulturae* 45: 12–14.
- Kataki, P. K., and S. C. Babu. 2002. *Food Systems for Improved Human Nutrition: Linking Agriculture, Nutrition and Productivity*. Binghamton, NY: Haworth Press, Inc.
- Katz, E. 1994. "The Impact of Non-traditional Export Agriculture on Income and Food Availability in Guatemala: An Intrahousehold Perspective." *Food and Nutrition Bulletin* 15 (4).
- Kennedy, E. 1994. "Approaches to Linking Agriculture and Nutrition Programmes." *Health Policy and Planning* 9 (3): 294–305.
- Kennedy, E., and H. E. Bouis. 1993. "Linkages between Agriculture and Nutrition. Implications for Policy and Research." Occasional Paper 28. IFPRI, Washington, DC.
- Kennedy, E., H. Bouis, and J. von Braun. 1992. "Health and Nutrition Effects of Cash-Crop Production in Developing Countries: A Comparative Analysis." *Social Science and Medicine* 35: 689–697.
- Kerr, R.B. 2006. *Contested Knowledge and Disputed Practice: Maize and Groundnut Seeds and Child Feeding in Northern Malawi*. Ithaca, NY: Cornell University.
- Kerr, R.B., and M. Chirwa. 2004. "Participatory Research Approaches and Social Dynamics That Influence Agricultural Practices to Improve Child Nutrition in Malawi." *EcoHealth* 1: 109–119.
- Kidala, D, T. Greiner, and M. Gebre-Medhin. 2000. "Five-Year Follow-up of a Food-Based Vitamin A Intervention in Tanzania." *Public Health Nutrition* 3 (4): 425–31.
- Kiess, L., M.W. Bloem, S. de Pee, A. Hye, T. Khan, A. Talukder, N. Huq, M. Haq, and M. Ali. 1998. "Bangladesh: Xerophthalmia Free. The Result of an Effective Vitamin A Capsule Program and Homestead Gardening." In *American Public Health Association 126th Annual Meeting Report*, 361. Washington, D.C: American Public Health Association.
- Kiess, L. R.Moench-Pfanner, and M.W. Bloem. 2001. "Food-Based Strategies: Can They Play a Role in International Development?" *Food Nutrition Bulletin* 22: 436–42.
- Krueger, A., M. W. Schiff, and A. Valdes, eds. 1991. *The Political Economy of Agricultural Pricing Policy*. Baltimore, MD: Johns Hopkins University Press.
- Kuipers, P. 2005. "South Africa's Two-Tiered Retail Sector." *Elsevier Food International* 8 (1) (February).
- Kumar, S., and C. Siandwazi. 1994. "Maize in Zambia: Effects of Technological Change on Food Consumption and Nutrition." In *Agricultural Commercialization, Economic Development, and Nutrition*, ed. J. von Braun and E. Kennedy, 295–308. Baltimore, MD: Johns Hopkins University Press.
- Kurz, K., and C. Johnson-Welch. 2007. "Enhancing Women's Contributions to Improving Family Food Consumption and Nutrition." *Food and Nutrition Bulletin* 22: 443–53.
- Lawrence, M., W. A. Coward, F. Lawrence, T. J. Cole, and R. G. Whitehead. 1987. "Fat Gain During Pregnancy in Rural African Women: The Effect of Season and Dietary Status." *American Journal of Clinical Nutrition* 45: 1442–50.
- Leroy, J. L., and E. Frongillo. Forthcoming. "Can Interventions to Promote Animal Production Ameliorate Undernutrition?" *Journal of Nutrition*.
- Leroy, J. L., C. F. Nicholson, M. W. Demment, T. F. Randolph, A. M. Pomeroy, and E. A. Frongillo. 2007. "Can Livestock Production Ameliorate Undernutrition?" February 2007 draft.
- Levinson, J. 1995. "Multisectoral Nutrition Planning: A Synthesis of Experience." In *Child Growth and Nutrition in Developing Countries—Priorities for Action*, ed. P. Pinstrip-Andersen, D. Pelletier, and H. Alderman, 262–82. Ithaca, N.Y.: Cornell University Press.
- Levinson, J. 2000. *Searching for a Home: The Institutionalization Issue in International Nutrition*. Washington, DC: World Bank.
- Low, J., M. Arimond, N. Osman, A. K. Osei, F. Zano, B. Cunguara, M. Selemene, D. Abdullah, and D. Tschirley. 2005. *Towards Sustainable Nutrition Improvement in Rural Mozambique: Addressing Macro- and Micro-Nutrient Malnutrition through New Cultivars and New Behaviors: Key Findings*. East Lansing, MI: State University Press.
- Low, J., M. Arimond, N. Osman, B. Cunguara, F. Zano, and D. Tschirley. 2007a. "A Food-Based Approach Introducing Orange-Fleshed Sweet Potatoes Increased Vitamin A Intake and Serum Retinol Concentrations among Young Children in Rural Mozambique." *Journal of Nutrition* 137.
- Low, J., M. Arimond, N. Osman, B. Cunguara, F. Zano, and D. Tschirley. 2007b. "Ensuring Supply and Creating Demand for a Biofortified Crop with a Visible Trait: Lessons Learned from the Introduction of Orange-Fleshed Sweet Potato in Drought-Prone Areas of Mozambique." *Food and Nutrition Bulletin*. Forthcoming.

- Lumpkin, T. A., K. Weinberger, and S. Moore. 2005. "Increasing Income through Fruit and Vegetable Production: Opportunities and Challenges." Draft note, CGIAR Science Forum, 6 December 2005, Marrakech, Morocco.
- Lynch, L. 1979. "Nutrition-Planning Methodologies: A Comparative Review of Types and Applications." *Food and Nutrition Bulletin* 1 (3): 1–14.
- Maheshwar, C., and T. S. Chanakwa. 2006. "Post Harvest Losses Due to Gaps in Cold Chains in India—A Solution." *Acta Hort* (ISHS) 712: 777–84.
- Mason, J. B. 2000. *How Nutrition Improves and What That Implies for Policy Decisions*. Washington, DC: World Bank.
- Maxwell, S., and T. Conway. 2000. "New Approaches to Planning." Operations Evaluation Department Working Paper Series No. 14. World Bank, Washington, DC.
- McClaren, D. S. 1974. "The Great Protein Fiasco." *Lancet* Jul 13 (2): 93–6.
- Meinzen-Dick, R., and M. Adato. 2007. "Impacts of Agricultural Research on Poverty: Synthesis of Findings and Implications for Future Directions." In *Agricultural Research, Livelihoods, and Poverty. Studies of Economic and Social Impacts in Six Countries*, ed. M. Adato and R. Meinzen-Dick, 331–67. Baltimore, MD: Johns Hopkins University Press for IFPRI.
- Meinzen-Dick, R., M. Adato, L. Haddad, and P. Hazell. 2004. "Science and Poverty: An Interdisciplinary Assessment of the Impact of Agricultural Research." *Food Policy Report*. IFPRI, Washington, DC.
- Mendez, M. A., and B. M. Popkin. 2004. "Globalization, Urbanization and Nutritional Change in the Developing World." *FAO Food and Nutrition Paper* 1 (2) 55–80.
- Minot, N., and D. Roy. 2006. "Impact of High Value Agriculture and Modern Marketing Channels on Poverty: A Conceptual Framework." IFPRI, Washington, DC (Photocopy).
- Mirle, C. 2006. *Predicting the Effects of Crop-Based Agricultural Programs on Household-Level Consumption in Rural Bangladesh: The Case of the Northwest Crop Diversification Program in Aditmari Upazilla, Northwest Bangladesh*. Boston, MA: Tufts University.
- Mody, A., R. Suri, and J. Sanders. 1992. "Keeping Pace with Change: Organizational and Technological Imperatives." *World Development* 20 (12): 1797–1816.
- Monsen, E. R. 1988. Iron Nutrition and Absorption: Dietary Factors Which Impact Iron Bioavailability. *Journal of American Diet Association* 88 (7): 786–90.
- Mullins, G., L. Wahome, P. Tsangari, and L. Maarse. 1996. Impacts of Intensive Dairy Production on Smallholder Farm Women in Coastal Kenya. *Human Ecology* 24 (2): 231–53.
- Mulokozi, G., L. Mselle, C. Mgoba, J. K. L. Mugyabuso, and D. G. Ndossi. 2000. *Improved Solar Drying of Vitamin A-Rich Foods by Women's Groups in the Singida District of Tanzania*. Research Program No. 5. Washington, DC: ICRW/OMNI (International Center for Research on Women/Opportunities for Micronutrient Interventions).
- Mwangwela, A. M. 2001. "Post Harvest Sector Challenges in Malawi." Paper presented at the FAO-GFAR Global Initiative for Post Harvest Technology Meeting, Entebbe, Uganda, September 17–19.
- Nalim, S. 1994. "The Impact of Fish in Enhancing Rice Field Ecology and in Integrated Pest Management." Summary report of the 3rd Asian Regional Rice-Fish Farming Research and Development Workshop, June 6–11, 1993, Sukamandi Research Institute for Food Crops, West Java, Indonesia. *ICLARM Conference Proceedings* 43.
- Narrod, C., D. Roy, K. Rich, J. Okello, B. Avendano, and A. Thorat. 2006. "The Role of Public-Private Partnerships and Collective Action in Ensuring Smallholder Participation in High Value Fruit and Vegetable Supply Chains." CAPRI Working Paper. IFPRI, Washington, DC.
- Naylor, R., W. Falcon, R. Goodman, M. Jahn, T. Sengooba, H. Tefera, and R. Nelson. 2004. "Biotechnology in the Developing World: A Case For Increased Investments in Orphan Crops." *Food Policy* 29: 15–44.
- Nestel, P., H. E. Bouis, J. V. Meenakshi and W. Pfeiffer. 2006. "Biofortification of Staple Food Crops." *Journal of Nutrition* 136 (April): 1064–67.
- Neven, D., T. Reardon, and H. Wang. 2006. "Supermarkets and Consumers in Africa: The Case of Nairobi, Kenya." *Journal of International Food and Agribusiness Marketing* 18 (1/2).
- Ngu, T., N. D. Quang, P. H. Ha, T. Giay, J. C. Badcock, and S. Fitzgerald. 1995. "A Food-Based Approach to Nutrition Improvement through Household Food Security in Vietnam, with Special Reference to Vitamin A Deficiency." In *Proceedings of 16th IVACG Meeting, Chang Rai, Thailand, 1994*. Washington, DC: International Life Sciences Institute (p. 77).
- Niamir-Fuller, M. 1994. *Women Livestock Managers in the Third World: A Focus on Technical Issues Related to Gender Roles in Livestock Production*. Rome, Italy: International Fund for Agricultural Development.
- Nielsen, H. 1996. "The Socio-Economic Impact of a Smallholder Livestock Development Project, Bangladesh, Integrated Farming in Human Development" (workshop); Danish Agricultural and Rural Development Advisers Forum, Tune Landboskole, Denmark.
- Nielsen, H., N. Roos, and S. H. Thilsted. 2003. "The Impact of Semi-Scavenging Poultry Production on the Consumption of Animal Source Foods by Women and Girls in Bangladesh." *Journal of Nutrition* 133 (11 Suppl 2): 4027S–30S.
- Niemeijer, R., and J. Hoorweg. 1994. "Commercialization of Rice and Nutrition: A Case from West Kenya." In *Agricultural Commercialization, Economic Development, and Nutrition*, ed. J. von Braun and E. Kennedy, 264–275. Baltimore, MD: Johns Hopkins University Press.
- Niemeijer, R., M. Guens, T. Kliet, V. Ogonda, and J. Hoorweg. 1988. "Nutrition in Agricultural Development: The Case of Irrigated Rice Cultivation in West Kenya." *Ecology of Food and Nutrition* 22: 65–81.
- Nugent, R. 2004. "Food and Agriculture Policy: Issues Related to Prevention of Noncommunicable Diseases." *Food Nutrition Bulletin* 25 (2): 200–7.
- Okello, J. 2005. "Compliance with International Food Safety Standards: The Case of Green Bean Production in Kenyan Family Farms." PhD dissertation, Michigan State University.
- Pacey, A., and P. Payne. 1985. *Agricultural Development and Nutrition*. London: Hutchinson.
- Paeratakul, S., B. M. Popkin, and K. Ge. 1998. "Changes in Diet and Physical Activity Affect the Body Mass Index of Chinese Adults." *International Journal of Obesity Related Metabolic Disorders* 22 (5): 424–31.
- PAHO (Pan American Health Organization.) 1990. *Primera Reunion de la red Latinoamericana de Vigilancia Epidemiologica de las Enfermedades*. VETA II, PAHO, Washington, DC.
- Parlato, M., and P. Gottert. 1996. "Promoting Vitamin A in Rural Niger: Strategies for Adverse Conditions." In *Strategies for Promoting Vitamin A Production, Consumption and Supplementation. Four Case Studies*, ed. R. E. Seidel. Washington, DC: Academy for Educational Development.
- PATH Canada. 2004. "Soils, Food, and Healthy Communities: A Participatory Agroecosystem Approach to Monitoring Change in Northern Malawi: Final Technical Report." Submitted to the International Development Research Center, Canada.

- Peduzzi, C. 1990. "Home and Community Gardens Assessment Program Implementation Experience: The Tip of the Iceberg." Vitamin A Field Support Project (VITAL) Report No. TA-2. International Life Sciences Institute, Washington, DC.
- Pelletier, D. L., K. Deneke, Y. Kidane, B. Haile, and G. Negussie. 1995. "The Food-First Bias and Nutrition Policy: Lessons from Ethiopia." *Food Policy* 20: 279–98.
- Pena, C., P. Webb, and L. Haddad. 1996. "Women's Economic Advancement through Agricultural Change: A Review of Donor Experience." Food Consumption and Nutrition Division Discussion Paper #10. IFPRI, Washington, DC.
- Phillips, M., T. Sanghvi, R. Suarez, J. McKigney, and J. Fiedler. 1996. "The Costs and Effectiveness of Three Vitamin A Interventions in Guatemala." *Social Science & Medicine* 42: 1661–8.
- Pingali, P. 2004. "Climate Change and Food Systems." Paper presented at the OECD Global Forum on Sustainable Development: Development and Climate Change, ENV/EPOC/GF/SD/RD(2004)11/FINAL, Paris, OECD (Organisation for Economic Co-operation and Development).
- Pinstrup-Andersen, P. 1982. "Introducing Nutritional Considerations into Agricultural and Rural Development." *Food and Nutrition Bulletin* 4 (2).
- Pinstrup-Andersen, P. 1981. *Nutritional Consequences of Agricultural Projects: Conceptual Relationships and Assessment Approaches*. Washington, DC: World Bank.
- Pinstrup-Andersen, P., and E. Schiöler. 2001. *Seeds of Contention: World Hunger and the Global Controversy over GM Crops*. Baltimore, MD: Johns Hopkins University Press.
- Pinstrup-Andersen, P., A. Berg, and M. Forman. 1984. *International Agricultural Research and Human Nutrition*. Rome, Italy: UN Administrative Committee on Co-ordination Sub-Committee on Nutrition. Washington, DC: International Food Policy Research Institute.
- Pokharel, C. 2003. "Agricultural Diversification in Nepal." Paper presented at the International Workshop on Agriculture Diversification and Vertical Integration in South Asia, November 5–7, 2003, New Delhi, India, jointly organized by ICRISAT, FICCI, and IFPRI.
- Popkin, B. M. 2002. "An Overview on the Nutrition Transition and Its Health Implications: The Bellagio Meeting." *Public Health Nutrition* 5, (1A): 93–103.
- Popkin, B. M. 2006. "Technology, Transport, Globalization And The Nutrition Transition Food Policy." *Food Policy* 31: 554–69.
- Popkin, B. M. 1999. "Urbanization, Lifestyle Changes and the Nutrition Transition." *World Development*. 27: 1905–16.
- Popkin, B. M., and S. Du. 2003. "Dynamics of the Nutrition Transition toward the Animal Foods Sector in China and Its Implications: A Worried Perspective." *Journal of Nutrition*. 133: 3898S–906S.
- Popkin, B. M., F. S. Solon, T. Fernandes, and M. C. Latham. 1980. "Benefit-Cost Analysis in the Nutrition Area: A Project in the Philippines." *Social Science & Medicine* 14C: 207–16.
- Pretty, J., and J. Hine. 2001. *Reducing Food Poverty with Sustainable Agriculture*. SAFE-World Project, Centre for Environment and Society, University of Essex, Colchester, UK.
- Price, G., R. Landes, and A. Govindan. 2003. "India's Pulse Sector: Results of Field Research." WRS-03-01, USDA/ERS (US Department of Agriculture/Economic Research Service).
- Pyakuryal, B., Y. B. Thapa, and D. Roy. 2005. "Trade Liberalization and Food Security in Nepal." MTID Discussion Paper, 88. IFPRI (International Food Policy Research Institute), Washington, DC.
- Quisumbing, A. 2003. *Household Decisions, Gender, and Development. A Synthesis of Recent Research*. Washington, DC: International Food Policy Research Institute/Baltimore, MD: Johns Hopkins University Press.
- Quisumbing, A., and J. Maluccio. 2000. "Intrahousehold Allocation and Gender Relations: New Empirical Evidence from Four Developing Countries." Food Consumption and Nutrition Division Discussion Paper #84. IFPRI (International Food Policy Research Institute), Washington, DC.
- Quisumbing, A., L. Brown, L. Haddad, and R. Meinzen-Dick. 1998. "Gender Issues for Food Security in Developing Countries: Implications for Project Design and Implementation." *Canadian Journal of Development Studies* 19: 185–208.
- Quisumbing, A., L. Brown, H. Feldstein, L. Haddad, and C. Pena. 1995. "Women: The Key To Food Security." Food Policy Report. International Food Policy Research Institute, Washington, DC.
- Ramakrishnan, U. 2002. "Prevalence of Micronutrient Malnutrition Worldwide." *Nutrition Review* 60(5 Pt 2): S46–52.
- Ravi C., and D. Roy. 2006. "Consumption Diversification in India: How Has It Been and How Will It Be?" Photocopy. IFPRI, Washington, DC.
- Ravi C., S. M. Dev, B. Viswanathan, A. Gulati and S. Ramachander. 2004. "Economic Liberalization, Targeted Programmes and Household Food Security: A Case Study of India." MTID Discussion Paper 68. IFPRI, Washington, DC.
- Reardon, T., and J. Berdegue. 2002. "The Rapid Rise of Supermarkets in Latin America: Challenges and Opportunities for Development." *Development Policy Review* 20 (4): 371–88.
- Rich, K. M., and C. A. Narrod. 2005. "Perspectives on Supply Chain Management of High Value Agriculture: The Role of Public-Private Partnerships in Promoting Smallholder Access." Draft.
- Roberfroid, M. 2002. "Global View of Functional Foods. European Perspectives. *British Journal of Nutrition* 87 (Supplement 2): S139–S143.
- Rokx, C. 2000. "Who Should Implement Nutrition Interventions?—The Application of Institutional Economics to Nutrition and the Significance of Various Constraints to the Implementation of Nutrition Interventions." Health, Nutrition, and Population Discussion Paper. World Bank, Washington, DC.
- Roos, N., M. M. Islam, and S. H. Thilsted. 2003. "Small Indigenous Fish Species in Bangladesh: Contribution to Vitamin A, Calcium and Iron Intakes." *Journal of Nutrition*, 133 (11 Suppl 2), 4021S–26S.
- Ruel, M. 2001. "Can Food-Based Strategies Help Reduce Vitamin A and Iron Deficiencies? A Review of Recent Evidence." *Food Policy Review* 5. International Food Policy Research Institute.
- Sahn, D. E., P. A. Dorosh, and S. D. Younger. 1997. *Structural Adjustment Reconsidered: Economic Policy and Poverty in Africa*. Cambridge and New York: Cambridge University Press.
- Sanders, J. H., B. I. Shapiro, and S. Ramaswamy. 1996. *The Economics of Agricultural Technology in Semiarid Sub-Saharan Africa*. Baltimore, MD: Johns Hopkins University Press.
- Schroeder, T. C., A. P. Berkeley, and K. C. Schroeder. 1995. "Income Growth and International Meat Consumption." *Journal of International Food and Agribusiness Marketing* 7(3): 15–30.
- Schroeder, D. G., R. Martorell, J. A. Rivera, M. Ruel, and J. P. Habicht. 1995. "Age Differences in the Impact of Nutritional Supplementation on Growth." *Journal of Nutrition*. 125: 1051S–59S.
- Scrimshaw, N. S., and M. Behar. 1976. *Nutrition and Agricultural Development*. New York and London: Plenum Press.

- SDPI (Sustainable Development Policy Institute). 2004. "Regoverning Markets: Securing Small Holder Producer Participation in Restructured National and Agri-Food Systems." Pakistan. www.regoverningmarkets.org. Accessed February 15, 2005.
- Shepherd, A. W. 2005. *The Implications of Supermarket Development for Horticultural Farmers and Traditional Marketing Systems in Asia*. Agricultural Management, Marketing and Finance Service, FAO. Rome, Italy: FAO.
- Shrimpton, R., C. G. Victora, M. de Onis, R. Costa Lima, M. Blossner, and G. Clugston. 2001. "Worldwide Timing of Growth Faltering: Implications for Nutritional Interventions." *Pediatrics* 107 (5): 1–7.
- Smitasiri, S. 2000. "A Comment on How the Nutritional Impact of Agricultural Innovations Can Be Enhanced." *Food and Nutrition Bulletin* 21 (4): 503–6.
- Smitasiri, S., and S. Dhanamitta. 1999. "Sustaining Behavior Change to Enhance Micronutrient Status: Community and Women-Based Interventions in Thailand." Research Report No. 2, ICRW/OMNI (International Center for Research on Women/Opportunities for Micronutrient Interventions). ICRW, Washington, DC.
- Smitasiri S., K. Sa-ngobwarchar P. Kongpunya, C. Subsuwan, O. Banjong, C. Chitchumroonechokchai, W. Rusami-Sopaporn, S. Veeravong, and S. Dhanamitta. 1999. "Sustaining Behavioural Change to Enhance Micronutrient Status through Community and Women-Based Interventions in Northeast Thailand: Vitamin A." *Food and Nutrition Bulletin* 20 (2): 243–51.
- Smith, L.C., H. Alderman, and D. Aduayom. 2006. "Food Insecurity in Sub-Saharan Africa. New Estimates from Household Expenditure Surveys." Research Report No. 146. International Food Research Policy Institute, Washington, DC.
- Soleri, D., D. A. Cleveland, and A. Wood. 1991a. "Vitamin A Nutrition and Gardens Bibliography." Vitamin A Field Support Project (VITAL), Report No. IN-1. VITAL, International Life Sciences Institute, Arlington, VA.
- Soleri, D., D. A. Cleveland, and T. R. Frankenberger. 1991b. "Gardens and Vitamin A: A Review of Recent Literature." Vitamin A Field Support Project (VITAL), Report No. IN-2. VITAL, International Life Sciences Institute, Arlington, VA.
- Solon, F., H. Briones, J. R. Fernandez, and L. B. Shafritz. 1996. "Moving to a long-term strategy: increasing vegetable gardening and consumption in the Philippines. In *Strategies for Promoting Vitamin A Production, Consumption and Supplementation. Four Case Studies*, ed. R. E. Seidel. Washington, DC: Academy for Educational Development.
- Solon, F., T. L. Fernandez, M. C. Latham, and B. M. Popkin. 1979. "An Evaluation of Strategies to Control Vitamin A Deficiencies in the Philippines." *American Journal of Clinical Nutrition* 32: 144–53.
- Sommer, A., and K. P. West. 1996. *Vitamin A Deficiency: Health, Survival and Vision*. New York: Oxford University Press.
- Spielman, D. 2007. "Pro-Poor Agricultural Biotechnology: Can the International Research System Deliver the Goods?" *Food Policy* 32: 189–204.
- Talukder, A., L. Kiess, N. Huq, S. de Pee, I. Darnton-Hill, and M.W. Bloem. 2000. "Increasing the Production and Consumption of Vitamin A-Rich Fruits and Vegetables: Lessons Learned in Taking the Bangladesh Homestead Gardening Programme to a National Scale." *Food and Nutrition Bulletin* 21 (2): 165–72.
- Tam, P. 2004. "Regoverning Markets: Securing Small Holder Producer Participation in Restructured National and Agri-Food Systems, The Case of Vietnam." www.regoverning-markets.org. Accessed February 15, 2005.
- Tangka, F., E. A. Ouma, and S. J. Staal. 1999. "Women and the Sustainable Development of Market-Oriented Dairying: Evidence from the Highlands of East Africa." International Sustainable Development Research Conference, Leeds, U.K.
- Teranishi, J. 1997. "Sectoral Resource Transfer, Conflict and Macro Stability in Economic Development: A Comparative Analysis." In *The Role of Government in East Asian Economic Development, Comparative Institutional Analysis*, ed. N. Aoki, Y. K. Kim, and N. Okuno-Fujiwara. Oxford: Clarendon Press.
- Thirtle, C., L. Beyers, L. Lin, V. McKenzie-Hill, X. Irz, S. Wiggins, and J. Piesse. 2002. *The Impact of Changes in Agricultural Productivity on the Incidence of Poverty in Developing Countries*. Report to Department for International Development (DfID). London & East Kilbride, UK.
- Thomas, H (ed.). 2006. *Trade Reforms and Food Security: Country Case Studies and Synthesis*. Rome, Italy: FAO.
- Thompson, P. M., P. Sultana, M. Nuruzzaman, and A. Firoz Khan. 2000. "Impacts of Aquaculture Extension on Pond Operators and the Rural Community," Tenth Biennial Conference of the International Institute of Fisheries Economics and Trade. Oregon.
- Thomson, E.C. 1978. "The Symbiosis of Scientist, Planner, and Administrator in Nutrition Program Implementation." In *Nutrition and National Policy*, ed. B. Winikoff, 393–423. Cambridge, MA: MIT Press.
- Thorbecke, E. 2000. "Agricultural Markets Beyond Liberalization: The Role of the State." In *Agricultural Markets Beyond Liberalization*, ed. A. van Tilburg, H. A. J. Moll, and A. Kuyvenhoven. Dordrecht, Netherlands: Kluwer Academic Publishers.
- Todd, E. 1997. "Epidemiology of Food-Borne Diseases: A World-Wide Review." *World Health Statistics* (50): 30–50.
- Tohill, B. C. 2004. "The Evidence on Fruits and Vegetables and Body Weight." Background Document 4-c. Prepared for the Joint FAO/WHO Workshop on Fruits and Vegetables for Health, Kobe, Japan, September 1–3, 2004.
- Tontisirin, K., and S. Gillespie. 1999. "Linking Community-Based Programs and Service Delivery for Improving Maternal and Child Nutrition." *Asian Development Review* 17: 33–65.
- Torero, M., and A. Gulati. 2004. *Connecting Small Holders to Markets: Role of Infrastructure and Institutions*. Washington, DC: International Food Policy Research Institute.
- Trueblood, M., and S. Shapouri. 2001. "Implications of Trade Liberalization on Food Security of Low-Income Countries: Agriculture Information Bulletin No. 765-5." (U.S. Department of Agriculture), Washington, DC.
- Tschirley, D., and M. Ayieko. 2005. "Changing Horticultural Supply Chains in Africa: Implications for Government and Donor Investments; Evidence from Kenya and Implications for Africa." Presentation at the World Bank, Washington, DC, April 6, 2005.
- UN SCN (United Nations Standing Committee on Nutrition). 2000. "Fourth Report on the World Nutrition Situation." UN SCN/IFPRI (International Food Policy Research Institute), Geneva, Switzerland.
- . 2004. "Fifth Report on the World Nutrition Situation: Nutrition for Improved Development Outcomes." UN SCN, Geneva, Switzerland.
- UNICEF (United Nations Children's Fund). 1990. *Strategy for Improved Nutrition of Children and Women in Developing Countries*. UNICEF Policy Review. New York: UNICEF.
- Unnevehr, L., and N. Hirschhorn. 2000. *Food Safety Issues in the Developing World*. World Bank Technical Paper 469, World Bank, Washington, DC.

- USDA (U.S. Department of Agriculture). 2002. "Thailand Retail Food Sector GAIN Report." Foreign Agricultural Service, USDA, Washington, DC.
- . 2003. "Indonesia Retail Food Sector GAIN Report," Foreign Agricultural Service, USDA, Washington, DC.
- . 2004a. "HRI Food Service Sector Thailand." Foreign Agricultural Service GAIN Report TH4030. Washington, DC. <http://www.fas.usda.gov/gainfiles/200403/146105693.pdf>.
- . 2004b. *Vegetables and Melons: Situation and Outlook Yearbook*. Washington, DC: Economics Research Service, USDA, July.
- Valdivia, C. 2001. "Gender, Livestock Assets, Resource Management, and Food Security: Lessons from the SR-CRSP." *Agriculture and Human Values* 18 (1): 27–39.
- von Braun, J. 1988. "Effects of Technological Change in Agriculture on Food Consumption and Nutrition: Rice in a West African Setting." *World Development*. 16: 1083–98.
- von Braun, J., and E. Kennedy (eds.). 1994. *Agricultural Commercialization, Economic Development, and Nutrition*. Baltimore, MD: Johns Hopkins University Press.
- von Braun, J., and E. Kennedy. 1986. "Commercialization of Subsistence Agriculture: Income and Nutritional Effects in Developing Countries." Working papers on commercialization of agriculture and nutrition. IFPRI (International Food Policy Research Institute), Washington, DC.
- von Braun, J., and E. Kennedy. 1994. *Agricultural Commercialization, Economic Development, and Nutrition*. Baltimore, MD: Johns Hopkins University Press.
- von Braun, J., H. de Haen, and J. Blanken. 1991. "Commercialization of Agriculture under Population Pressure: Effects on Production, Consumption, and Nutrition in Rwanda." Research Report #85. IFPRI, Washington, DC.
- von Braun, J., K. Johm, and D. Puetz. 1994. "Nutritional Effects of Commercialization of a Woman's Crop: Irrigated Rice in The Gambia." In *Agricultural Commercialization, Economic Development and Nutrition*, ed. J. von Braun and E. Kennedy, 343–62. Baltimore, MD: Johns Hopkins University Press.
- Wang, J., and D. Ni. 1995. "A Comparative Study of the Ability of Fish to Catch Mosquito Larvae." In *Rice-Fish Culture in China*, ed. K. T. Mackey. Ottawa, Canada: IDRC.
- Waterlow, J. C., and P. R. Payne. 1975. "The Protein Gap." *Nature* 258: 113–17.
- Weerahewa, J. 2004. "Impacts of Trade Liberalization and Market Reforms on the Paddy/Rice Sector in Sri Lanka." MTID Discussion Paper 70. IFPRI, Washington, DC.
- Weinberger, K., and T. Lumpkin. 2005. "High Value Agricultural Products in Asia and the Pacific for Smallholder Farmers: Trends, Opportunities and Research Priorities." Paper presented at workshop *How the Poor Benefit from Growing Markets for High Value Agricultural Products*. CIAT Headquarters, Cali, Columbia. AVRDC.
- Wellenius, B. 1993. *Telecommunications. World Bank Experience and Strategy*. Washington, DC: World Bank.
- West, K. P. 2002. "Extent of Vitamin A Deficiency among Preschool Children and Women of Reproductive Age." *Journal of Nutrition* 132: 2857S–66S.
- West, C. E., A. Eilander, M. van Lieshout. 2000. "Consequences of Revised Estimates of Carotenoid Bioefficacy for Dietary Control of Vitamin A Deficiency in Developing Countries." *Journal of Nutrition* 32: 2920S–26S.
- WHO (World Health Organization). 2002. *Food Safety and Food-Borne Illness*. Geneva, Switzerland: WHO.
- . 2006. "Obesity and Overweight: WHO Fact Sheet." <http://www.who.int/mediacentre/factsheets/fs311/en/index.html>. Accessed November 28, 2006.
- . 2005. *Preventing Chronic Diseases A Vital Investment*. Geneva, Switzerland: WHO.
- WHO (World Health Organization) and FAO (Food and Agriculture Organization). 2006. *Guidelines on Food Fortification with Micronutrients*, ed. L. Allen, B. de Benoist, O. Dary, R. Hurrell. WHO and FAO.
- . 2003. *Joint WHO/FAO Expert Consultation on Diet, Nutrition and the Prevention of Chronic Diseases*. WHO, Geneva, Switzerland.
- Wickramasinghe P. J., T. Abeysekera, and A. Herath. 2003. "Agricultural Diversification in Sri Lanka." Paper presented at the International Workshop on Agricultural Diversification and Vertical Integration in South Asia, November 5–7, New Delhi, India, jointly organized by ICRISAT, FICCI, and IFPRI.
- Wild, S., G. Roglic, A. Green, R. Sicree, and H. King. 2004. "Global Prevalence of Diabetes: Estimates for 2000 and Projections for 2030." *Diabetes Care* 27: 1047–53.
- Williams, G. W. 1984. "Development and Future Direction of the World Soybean Market." *Quarterly Journal of International Agriculture* 23: 319–37.
- Winikoff, B. 1978. "Program and Policy: Some Specific Questions." In *Nutrition and National Policy*, ed. B Winikoff, 523–46. Cambridge, MA: MIT Press.
- World Bank. 2006a. *Repositioning Nutrition as Central to Development: A Strategy for Large-Scale Action*. World Bank, Washington, DC.
- . 2006b. "Aquaculture: Changing the Face of the Waters. Meeting the Promise and Challenge of Sustainable Aquaculture." Report No. 36622.GLB. World Bank, Washington, DC.
- . 2006c. *China's Compliance with Food Safety Requirements for Fruits and Vegetables: Promoting Food Safety, Competitiveness and Poverty Reduction*. World Bank, Washington, DC and Beijing, China.
- . 2005. "From Competition at Home to Competing Abroad: The Case of Indian Horticulture" (photocopy). World Bank, Washington, DC.
- . 2005a. *Agriculture and Achieving the Millennium Development Goals*. Report No. 32729-GLB. World Bank and IFPRI, Washington, DC.
- . 1986. *The Hesitant Recovery and Prospects for Sustained Growth, Trade and Pricing Policies in World Agriculture*. New York: Oxford University Press.
- . 2004. "Saving Fish and Fishers." Report No 29090-GLB. World Bank, Washington, DC.
- Yach, D., C. Hawkes, C. L. Gould, and K. J. Hofman. 2004. "The Global Burden of Chronic Diseases: Overcoming Impediments to Prevention and Control." *Journal of the American Medical Association* 291: 2616–22.



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