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**LINKAGES BETWEEN
AGRICULTURE AND NUTRITION:
IMPLICATIONS FOR
POLICY AND RESEARCH**

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Foreword

Whereas there was a tendency in the 1960s to exaggerate the importance of linkages between agriculture and nutrition, during the 1980s such linkages were often belittled. In the earlier decade a stable and sufficiently high level of food production in low-income countries was often considered to be adequate for good nutrition, but through the years the perception grew that agricultural production and food availability were not particularly relevant to favorable nutritional outcomes. These two extreme positions, both of which failed to recognize the important role of agricultural development in improved nutrition, need to be put in perspective.

This paper by Eileen Kennedy and Howarth E. Bouis contributes to a rationalization of the debate. Re-edited here, the paper was originally presented at the International Conference on Nutrition, held in 1992 in Rome under the auspices of FAO and WHO. It offers the opportunity to prevent further undue swinging of the pendulum by putting the relationships between agriculture and nutrition into a broad conceptual framework, delineating the important ties that technological change and modernization in agriculture have to human behavior and nutrition, and pointing out future research needs. Progress in nutritional improvement can be achieved only if progress in agricultural development is sustained.

Other complementary actions in the fields of health, education, and politics are, of course, also necessary for improved nutrition, and the paper, which draws on extensive research by IFPRI and others, addresses those concerns as well.

Joachim von Braun
Director
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Introduction

Despite considerable progress in understanding the nature and causes of malnutrition, it continues to be a problem of staggering proportions throughout the world (UN/ACC-SCN 1993). A conservative estimate of the magnitude of the problem indicates that 36 percent of preschool-aged children (from birth to six years of age) in developing countries are moderately or severely malnourished based on weight-for-age (Carlson and Wardlaw 1990). In addition, based on preliminary estimates of the Sixth World Food Survey, 20 percent of the population or approximately 1 billion people in developing countries are energy-deficient (FAO 1992).¹ This is clearly an underestimate of the nutrition problem, since it is based solely on caloric deficits. If nutritional disorders in women and children, such as anemia and vitamin A and iodine deficiency, were included, the number would be much larger.

What is clear is that the magnitude of the problem, regardless of varying estimates, is intolerable. In addition to the human suffering it causes, malnutrition has negative effects on labor productivity, cognitive development, and health. Malnutrition constrains an individual's long-term capability for taking advantage of economic opportunities. Many policymakers and donors believe that long-term, sustained economic growth is the most effective way of dealing with the malnutrition problem. Since the economies of many developing countries are based heavily on agriculture, growth in the agricultural

sector through technological change is viewed as a key means of generating this economic growth. However, this long-term perspective does little to deal with the short-term acute malnutrition problem.

This paper reviews the important links between agriculture and nutrition and in doing so tries to elucidate what is known about the linkages between agricultural research, technological change in agriculture, and nutrition. Using lessons learned from prior experience, the paper identifies agricultural policies and programs that offer a high potential of bringing about improvements in the health and nutritional status of the population.

The next chapter provides a conceptual framework outlining the links between agricultural research, agricultural and food policies, and nutritional status. That is followed by a chapter that summarizes the major areas of agricultural research over the past 20-30 years. In this chapter, research is defined in a broad sense and thus includes both basic biological research as well as the more applied, policy-oriented research. Next is a review of how this investment in agricultural research has influenced the agricultural technologies that have been implemented in developing countries. Another chapter is devoted to other, non-technological issues that can affect the success of agricultural innovations in alleviating malnutrition. Finally, the paper identifies areas for future agricultural research and government policy that offer a high potential for nutritional impact.

¹ Based on the proportion of the population below 1.5 Basal Metabolic Rate.

Conceptual Framework for Agriculture/Nutrition Linkages

Malnutrition manifests itself at the level of the individual, but the causes of malnutrition are typically a combination of individual, household, community, national, and even international factors. The schema outlined in Figure 1, which illustrates the broad linkages between agriculture and the health and nutritional status of individuals, highlights the policies on which this paper focuses.

Agricultural research is assumed to have its most direct impact on nutritional status through the effect on food prices and wages. However, by influencing the choice of technology that is adopted, agricultural research may also have an effect on the community health and sanitation environment. These direct and indirect effects of agricultural research are discussed in Chapters 3 and 4.

There are three main pathways through which agricultural policies and programs influence the nutritional status of individuals: (1) increased incomes and lower food prices, which permit increased food consumption; (2) effects on the health and sanitation environment at the household and community levels, which may increase or reduce morbidity; and (3) effects on time-allocation patterns, particularly of mothers, which may increase or reduce time spent on nurturing activities—time that is often related to women's control over household income and is an important determinant of women's nutritional status. These three pathways have been identified in other theme papers for the International Conference on Nutrition, but not in relation to how agricultural policy influences one or more of these determinants of health and nutritional status.

At the top of Figure 1, the household has a fixed amount of time and capital that it must decide to allocate among various income-generating activi-

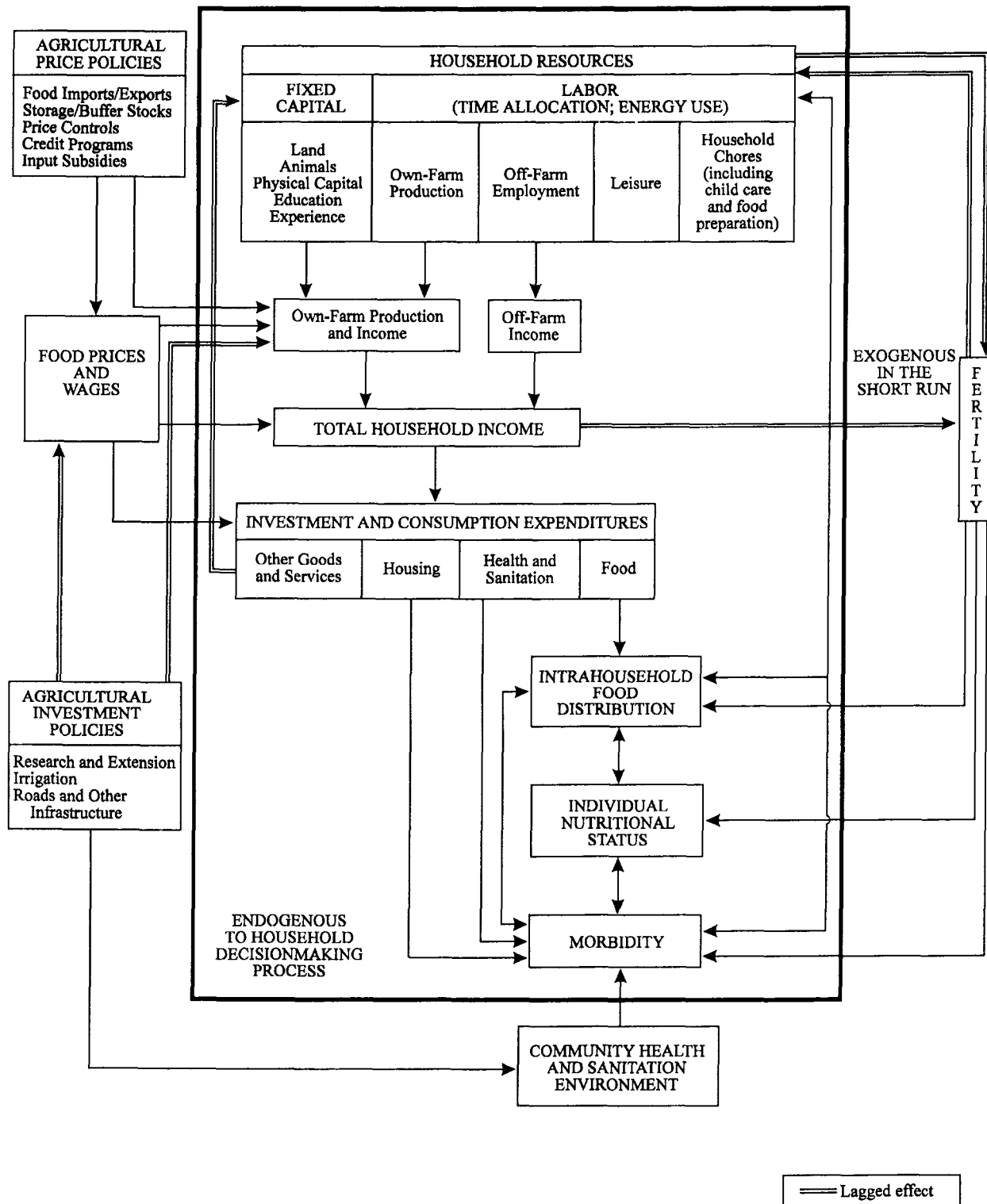
ties, given exogenous prices for consumer goods and production inputs and outputs, with the objective of maximizing the well-being of individual household members through consumption expenditures, leisure time, and better nutrition. Depending on how those resources are allocated to own-farm production activities and off-farm employment, a certain amount of cash and in-kind income is generated that can then be spent on various consumption items. One of the primary linkages is food expenditures: how they increase with higher incomes, the extent to which nutrient availability is enhanced by these extra food expenditures at the household level, and how these nutrients are distributed among various household members. Finally, as shown at the bottom of Figure 1, nutrient intakes are an important determinant of nutritional status.

However, nutrient intakes are not the only link through which household allocation decisions affect nutritional status. Morbidity is an important determinant of appetite and of how well nutrients are absorbed by the body. The household that earns less income because it allocates more time to food preparation and child care could enjoy better nutrition, because of reduced morbidity, than if it had earned extra income and spent more for food. Other links between production and nutrition should be added to the diagram, but that would result in a diagram much too crowded to be helpful.²

Unfortunately, the complexity of these interrelationships went unrecognized or was ignored in the past, which led to simplistic policy recommendations. An implicit assumption during the early dissemination of modern cereal varieties—often dubbed the "green revolution" technologies—was that increasing yields was a sufficient condition for improving nutritional status (Harriss 1987); most

² More detailed information on each of these links, for example the links between a mother's nutritional status during pregnancy and breast-feeding and her infant's nutritional status, is contained in von Braun and Kennedy (1986).

Figure 1—Agricultural policies, household resource allocation, and nutrition



policymakers believed that inadequate food supply was the major cause of malnutrition. Thus, much of the early emphasis in developing agricultural technologies was placed on increasing national-level food supplies via increased agricultural production.

Achieving a sufficient food supply is indeed one part of a strategy to ensure household food security (von Braun et al. 1992). But while food availability at the national, regional, or local village level is one factor that can influence household-level food availability, it is not necessarily the most important. For example, it is common to have 20-30 percent of a country's population consuming less than 80 percent of caloric requirements even though national-level food availability is at or greater than 100 percent (World Bank 1986). It is the household's ability to obtain food when it needs it that is critical in ensuring household food security; to the extent that technological change in agriculture increases access to food (through higher incomes or lower food prices or both), household food security will improve.

An increase in household food intake often is assumed to improve the food intake of each of the household members. But results from a number of studies now indicate that household consumption is often a poor proxy for an individual's caloric intake (Garcia and Pinstrup-Andersen 1987). This is because the effect of increases in household food access on an individual member's food consumption can be modified by a variety of factors including intrahousehold income-earning patterns, the education of household members, and characteristics of the individual such as gender, age, birth order, and genetic endowment. The strength and direction of each of these factors vary by sociocultural environment.

In some cultures (mainly in South Asia), boys get preferential treatment in the allocation of food and other resources. But there is little evidence of this gender bias in the allocation of food in Africa (Svedberg 1990). Outside of Africa, however, a number of studies have shown that children and women tend to consume a lower proportion of their caloric requirements relative to other household members (Haaga and Mason 1987; McGuire and Popkin 1989; Piwoz and Viteri 1985).

There are also differences in the allocation of health care among various types of household members. Again, most of the empirical evidence on intrahousehold gender bias comes from South Asia; a study in the Punjab found that in the first two years of life (years of peak mortality), expenditures for medical care for sons were 2.34 times higher than for daughters (Das Gupta 1977). Das Gupta concludes that gender bias in the Punjab is culturally determined and related to the structure of the rights

of asset ownership and decisionmaking, which severely restricts women's authority. Similar findings on maldistribution of medical expenditures were reported for Bangladesh; boys were favored over girls in the allocation of health care (Chen, Huq, and D'Souza 1981).

The education of a child's mother can play an important role in the effect of increased household resources—including food—on the child's consumption and nutritional status. More-educated women often exhibit behaviors that are more child-centered, which leads to better feeding practices and ultimately to healthier and better-nourished children (Tucker and Sanjur 1988). This maternal education effect on child nutrition has been documented for both formal and informal education of mothers.

More subtle factors, such as the decision-making power of the child's caretaker, influence intrahousehold allocation of resources and so may determine nutritional outcomes to a significant extent. There has been a strong belief that the greater the maternal control over how household income is spent, the more resources will be given to children in the form of better dietary intake and more health care and consumption goods. Until recently, there was very little empirical information to support or refute this position.

New evidence suggests that in certain types of female-headed households where women have more decisionmaking power, mothers allocate a larger share of household food supplies to preschool-aged children (Kennedy and Peters 1992). Other data from Malawi indicate that at low levels of income, children from some types of female-headed households are healthier than children from higher-income male-headed households. Similarly, recent evidence from Brazil indicates that female-headed households were able to use scarce resources (such as land, labor, capital, and credit) to improve short-term nutritional status for their children (Vosti and Witcover 1990). In view of the demographic shifts that are occurring in developing countries—in particular, the growing number of female-headed households—it is important to understand how different household structures influence the success or failure of particular agricultural policies and programs.

In examining the links between household consumption and an individual's food intake, prior research has concentrated on dietary energy as a proxy for the overall nutrient quality of the diet. Some recent studies suggest that energy may not be a sensitive measure of overall nutrient consumption. Evidence from Indonesia shows that vitamin A consumption was low in communities with low prevalence rates of protein-energy malnutrition; conversely, communities with a high prevalence of

protein-energy malnutrition, in general, had adequate consumption of vitamin A.

Similarly, a multicountry analysis showed that high caloric intake of preschool-aged children was not accompanied by high levels of consumption of all nutrients (Kennedy and Payongayong 1992). Again, vitamin A was one of the nutrients that did not increase concurrently with a rise in caloric intake. Vitamin A is particularly important because it is a nutrient known to be lacking in large segments of the child population in developing countries. In a number of large field trials, vitamin A supplementation has been shown to be associated with decreased mortality and, in some cases, a decrease in morbidity.

The health and sanitation environment and the nurturing behavior of caretakers may be as important as food intake, or in some cases more important, in influencing an individual's nutritional status. It may not be readily apparent how agricultural policies and programs influence the health and sanitation environment and nurturing behaviors. However, these linkages are more important than once thought.

For example, the unrestrained use of certain types of pesticides or the introduction of irrigation may have negative health effects (Vosti, Reardon, and von Urff 1991). Similarly, if agricultural policies and programs change the allocation of time within the household, because of increased or altered labor requirements, the time devoted to nurturing behaviors may also change. For these reasons, there needs to be a clear understanding of

the range of linkages between household income-generation and an individual's nutritional status. Therefore, this review goes beyond food-linked malnutrition.

Caring activities are critically important in influencing child health. This encompasses activities such as breast-feeding and weaning practices, child care, and other nurturing activities, all of which may be reduced if new agricultural technologies put added demand on women's time. Time-allocation studies indicate that, on average, women in developing countries put in more hours per day in non-leisure activities than do men (Juster and Stafford 1991). Not only are women actively engaged in own-farm production and wage-earning activities, but a substantial amount of a woman's day is devoted to home production such as child care, food preparation, cleaning, and collecting water and fuel.

Many of the health-promoting strategies such as growth monitoring and oral rehydration, which have been advocated as part of the child-survival revolution, add to the demands on women's time. The low level of utilization of some of these health strategies may be related to the lack of time of the mother (Leslie 1989).

In order to understand the net effect of agricultural policies and programs on nutrition, it is important to ascertain their effects on (1) food prices and household income; (2) sickness; and (3) time allocation, especially in association with nurturing activities. Changes in these three areas, in turn, have to be related to their effect on the nutritional status of children and adults.

Investment in Agricultural Research

Before 1950, agricultural research systems in developing countries, established originally under colonial rule, focused primarily on export crops such as sugar, tea, coffee, cocoa, and cotton. There were no significant research programs on root crops, oilseeds, pulses, sorghum, millets, and feedgrains, and but a few small programs on rice and wheat (de Janvry and Dethier 1985). In the 1950s and 1960s, developing-country policies were geared toward rapid industrialization through import substitution. Again, research on food crops was given low priority (Evenson 1984).

In the late 1960s and early 1970s, worldwide attention was focused on the problem of food shortages in developing countries. Rapid population growth exacerbated shortages of food caused by the underlying constraints to food production and distribution in many areas of the world. These food shortages were related to the lack of (1) natural resources, (2) incentives to produce, (3) purchasing power of the poor, and (4) appropriate institutions and infrastructure (Kennedy and Haddad 1992).

The international agricultural research system was developed in response to this situation, following the initial successes of the International Rice Research Institute (IRRI) and the Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT), and culminating in the creation in 1971 of the Consultative Group on International Agricultural Research (CGIAR), a system that now comprises 18 research institutes located all over the world. These research centers have given high priority to the wide adaptability of genetic material. At the same time, national research programs were developed and expanded to adapt this genetic material to specific growing environments (de Janvry and Dethier 1985; Piniero and Trigo 1983).

De Janvry and Dethier (1985) estimate that global agricultural research expenditures (by developed and developing countries) in 1984 were on the order of US\$10 billion, undertaken by about 200,000 scientists, and that US\$5 billion was spent on extension, involving roughly twice as many personnel. The CGIAR system accounted for 2 percent of all agricultural research expenditures and 15 percent of research expenditures in less-developed countries. Boyce and Evenson (1975) estimated that international aid accounted for between 40 and 50 percent of total research expenditures in less-developed countries in the 1960s. That share dropped to less than 20 percent in the early 1970s and then rose once again in the late 1970s (de Janvry and Dethier 1985).

Ratios of commodity-specific estimates of investments in agricultural research over value of total production (de Janvry and Dethier 1985, using figures from Judd, Boyce, and Evenson 1984) suggest that such investments are less than 1 percent, on average, of total value. Although these ratios are low in absolute value for all agricultural commodities, they tend to be much higher for export crops relative to food crops.

The very high rates of return to investments in agricultural research found by an overwhelming majority of studies in the literature suggest that such investments should be substantially increased. However, support for the CGIAR centers has remained about level over the past decade and there has been a decline in international support for agricultural investments in general. The next chapter discusses the generally beneficial impact that past investments in such research have had on levels of food consumption, focusing on both the agricultural research/technology links as well as the agricultural research/policy links.

Modernization and Technological Change in Agriculture

NEW SEED VARIETIES

The investments in agricultural research resulted in technologies that rely heavily on the modern seed varieties and had dramatic effects on food production, most notably in Asia and Latin America; (Pinstrup-Andersen and Hazell 1985). The increases in agricultural production resulted in lower food prices, which directly benefited the urban consumer, the rural landless, and the smallholder producer who was a net purchaser of food. In rural areas, the production increases resulting from use of the new technologies raised household incomes. For example, in North Arcot, India, households that adopted the new rice varieties more than doubled the real value of consumption of food and other consumer goods between 1973 and 1983/84 (Hazell 1987); there was also a shift toward more varied diets within these households.

Technological change in agriculture has also generated increased demand for hired labor and has thus provided a means of increasing the income of the rural landless. Recent evidence suggests that the use of labor per hectare in crop production appears to have diminished somewhat in what is seen as the second phase of the green revolution (Binswanger and von Braun 1991). It is estimated that the new technologies initially increased labor demand by about 25 percent. However, the labor requirements for rice production have declined somewhat since 1973/74 because of the increased mechanization of irrigation pumping and paddy threshing. While the global output of food supplies has increased because of high-yielding cereals, the pattern of growth across regions of the world has been uneven and variable through time (Anderson 1985). The un-irrigated areas of Asia suffer energy deficiencies at least as severe as 10-15 years ago, and most of Africa is without modern varieties and is poorer than in the 1970s (Anderson 1985). A mitigating factor is that in some instances household migration has occurred from less favorable to more favorable

growing environments where modern varieties have substantially increased productivity. This is not to argue that the green revolution technologies have been ineffective but, rather, that additional approaches have to be pursued for regions that have been missed by these technological breakthroughs.

In Africa the main staples include millet, sorghum, cassava, and maize. With the exception of high-yielding varieties of maize in eastern and southern Africa, few breakthroughs have occurred in the production of millet and sorghum in Africa (Matlon and Adesina 1991). As a result, area devoted to millet and sorghum cultivation has expanded by about 1.0 percent per year in response to rapid population growth, and fallow periods have declined. This may have negative implications for the sustainability of yields in the future because nutrient replacement in the soil often does not occur.

Some pioneering work of FAO on Integrated Plant Nutrition Systems for Development (IPNS) has attempted to counteract this problem; IPNS attempts to maintain soil fertility and thus sustain crop productivity through cultivation of cropping patterns that allow nutrients to be replenished in the soil.

The modernization of agriculture that has taken place over the past 25 years has involved heavy reliance on purchased inputs. Increased use of fertilizer and pesticides in combination with the new seed varieties has contributed to the production increases that have been observed. Despite the higher input costs, the increased agricultural output with technological change has resulted in a decreased cost of production per unit of output.

However, this growth in foodgrain production in most countries has also been accompanied by an increase in the variability of production. In India, the variance of national cereal production around the trend increased 240 percent between the early 1950s and 1977 (Hazell 1987). More recently, however, a further troubling development is that, although the rate of growth in rice and wheat yields per hectare

has increased in some countries in Asia (most notably Bangladesh and India), overall there has been a sharp decline in the rate of growth of yields in the past decade (Rosegrant and Svendsen 1992; Bouis forthcoming).

Recently, concern has also been voiced over the changing mix of crops cultivated in areas where the new seed varieties have been adopted. For example, in areas of India where the high-yielding seeds have been used there appears to have been a decline in the cultivation of pulses (Sarma and Gandhi 1990). This decreased pulse production has led to dramatic increases in the market price of pulses, which has led to decreased purchase and consumption. Recent data from India indicate that consumption of pulses per capita in India declined from 23.0 kilograms per year in 1981 to 13.4 per year in 1990 (Garcia 1992). Since pulses are a main source of iron consumption in developing countries, changing production and consumption patterns can have implications for micronutrient status. Diversity in crop production needs to be maintained in tandem with an emphasis on yield-increasing technologies.

Concern has been expressed recently that the indiscriminate use of fertilizers and pesticides has had negative effects on the environment. The negative effects of agricultural intensification have included loss of soil due to deforestation, waterlogging, and salinization; contamination from pesticide residues and resistance of insects, weeds, and pathogens to present methods of control; and loss of natural resources (water, soil, biodiversity) (Vosti, Reardon, and von Urff 1991). Future development of technologies has to devote attention to both productivity increases and sustainability.

Because the production increases made possible by the new seed varieties are dependent on higher levels of inputs than are the traditional cereals, wealthier farmers have typically been quicker to bear the risk of adopting modern varieties. However, most research has shown these technologies to be scale neutral, so over the longer run, small farmers adopt at equal rates (Anderson 1985).

Development and dissemination of modern cereal varieties over the past 25 years have dramatically increased food production. It is estimated that the successes in wheat and rice breeding increased global production of these commodities by about 40 million metric tons (Herdt and Capule 1983). The resulting supply expansion has resulted in decreased food prices that have benefited the poor. In addition, there were income and employment benefits for many of the households directly or indirectly involved with the technologies via multiplier effects for the rest of the economy, resulting in strong income/food consumption links. However, there are large gaps in current understanding of the links

between a household's adoption of new seed varieties and an individual's nutritional status.

Research on quality protein maize (QPM) in Guatemala by Valverde and others, discussed in Tripp 1984, was among the few studies to examine the direct links between modern varieties and individual nutritional status. Adoption of QPM was successful in improving the nutritional status of children under two years of age when the QPM was substituted for the local maize in the child's diet. Despite the effectiveness of QPM in improving nutritional status, the improved seed has never experienced widespread adoption by farmers in the region. Farmers prefer the taste of the local maize over the QPM. This has led some policymakers to favor alternative approaches—such as fortification of foods normally consumed—in improving diets, particularly diets of children.

One additional study (Lele 1989) examined the links between cultivation of hybrid maize in southwestern Kenya and the nutritional status of preschool-aged children. The government of Kenya has been advocating the adoption of hybrid maize by smallholders as a means of generating increased returns to land. The adoption rates of hybrid maize for the country as a whole have been quite good relative to other countries in Africa. It is estimated that approximately 30 percent of all maize grown in Kenya is the hybrid variety (Lele 1989).

The assumption has always been that adoption of hybrid maize would benefit the smallholder producer, since returns to land and labor would be significantly better for the hybrid than for the alternative local maize production. Data collected in southwestern Kenya were used to assess the impact of adoption of hybrid maize on smallholders, including effects on preschoolers' nutritional status. The data cover a multiyear period and thus provide the opportunity to cover a normal production period (1986) as well as a low production period caused by low rainfall (1984).

In 1984, which was a drought year for Kenya, maize yields were similar for both hybrid and local maize, suggesting little advantage in using the purchased hybrid maize seeds. In 1984 the poor performance of the hybrid variety of maize was thought by the government to be partially the result of the poor climatic conditions. However, in 1986, which was an average rainfall year for the area, there was again no significant difference between the yields for local and hybrid maize in the study area.

Adverse climatic conditions in 1984 were but one reason for lower-than-expected yields of hybrid maize. Use of fertilizer, particularly inorganic fertilizer, is extremely low for any type of food

crop. Only 29.4 percent of farmers use any type of fertilizer on hybrid maize, and of those, only 35 percent use inorganic fertilizer.

Thus the major reason for the poor yield response to the hybrid maize seed in this setting in both a drought and nondrought period is the lack of use of appropriate inputs. Since yields for unfertilized hybrid maize are no higher than those for local maize, the hybrid has no positive impact on the income, food security, or nutrition of adopting households.

There are numerous examples from the developing world, including Africa, of hybrid varieties outperforming the traditional maize. Recently, however, a number of countries have shown trends toward declining yields of both hybrid and local varieties of maize. Clearly, it is not the lack of technology that is driving this falling production but, rather, low adoption rates of improved technologies at the household and community levels, and possibly the national level.

The previous examples of quality protein maize in Guatemala and hybrid maize in Kenya illustrate that it was the failure to implement the technology, not the lack of a technical solution, that was the major constraint to agriculture's ability to improve nutrition. In Kenya, the use of incorrect input packages negated the potentially positive impact of the new seed variety. In Guatemala, the organoleptic characteristics (taste, color, odor) of the improved maize made it less desirable to households and thus unlikely to be permanently adopted. One cannot generalize about the nutritional impacts of the new seed varieties from two examples. However, these examples point to the need for involving users of the research—governments, communities, and households—from its inception in order to better understand the constraints to adoption at all levels.

While a lot is known about agricultural research/technology/food consumption links, there is a glaring gap in present knowledge of the effects of various types of agricultural research and their ultimate impacts on nutritional status. The only two studies that directly examine the links between development of new seed varieties and their impact on nutrition are those cited in this paper. Much more needs to be known about the range of consumption and nutrition effects associated with yield-increasing and other agricultural technologies.

IRRIGATION

Man-made irrigation has been critical to the success of the new seed varieties. Much of the agricultural production and increased income generated by the use of modern cereal varieties can be

attributed directly to the expanded use of irrigation. Some 60 percent of all grain production in developing countries is produced on irrigated land. Expansion of irrigation is essential for ensuring continued national-level food security (de Haen 1991).

The annual rate of growth in production of all cereals in Asia (excluding China and India) was 3.4 percent for the period from 1961/65 to 1979/85; some of this production increase was due to the increased availability of irrigation. In Africa, where man-made irrigation is less extensive, the growth rate in total cereal production was 1.5 percent during the same period, reflecting in part the low availability of ready and constant water sources.

Appropriate irrigation technology will continue to be a key factor for increasing agricultural production in arid and semi-arid areas of the world. Irrigation will be particularly critical in countries that are experiencing rapid population growth and do not have technological breakthroughs in agriculture for the short to medium term. Large parts of West Africa, the drier portions of northeast Africa, and the borderlands of the Kalahari Desert in southern Africa are examples of such areas (Moris and Thom 1987). However, the type of water management project that is developed may be quite different from the prototype of the large-scale irrigation projects of the 1960s and 1970s. Medium- and small-scale irrigation hold potential for many parts of Sub-Saharan Africa (Barghouti and Le Moigne 1990). In many countries, expansion of tubewell systems seems promising for providing cost-effective irrigation systems (Rosegrant and Svendsen 1992). And irrigation will continue to be important for the expansion of many of the chief export crops produced by developing countries.

The variability of rainfall in many arid regions, including much of Sub-Saharan Africa, limits livestock production. The marked seasonality in the nutrient consumption of livestock in Africa is a primary constraint to livestock production (Moris and Thom 1987); the long dry seasons that inhibit crop production have a similar effect on the natural vegetation for livestock. Irrigation schemes that ensure a continued source of water can help livestock development.

While irrigation will continue to be important in generating increased agricultural production per unit of land, problems have included cost overruns, weak institutions leading to deteriorating maintenance and declining output, poor technical design, and, most important for the purposes of this review, environmental effects leading to an increased incidence of disease (Barghouti and Le Moigne 1990). More than any other type of agricultural technology, irrigation has been associated with negative health effects, particularly in Sub-Saharan Africa. The

transmission of disease may be through direct contamination, as in the case of cholera, or may be the result of favorable conditions for the growth of parasitic vectors, as in the cases of malaria, schistosomiasis, and river blindness (von Braun 1991).

A number of studies in Africa have shown that the development of irrigated rice schemes often results in an increased prevalence of schistosomiasis. For example, in Sudan's Gezira Irrigation Scheme, it was estimated that prior to the development of the project, schistosomiasis was nonexistent; however, after 15 years of operation, 30 to 60 percent of the resident population had been infected with schistosomiasis (FAO 1986). Similarly, in Egypt, three years after the development of the Aswan Dam, 60 percent of the population was infected.

Rates of malaria also appear to increase in areas where irrigation is added. However, in environments already infected with malaria—for example, the Gambia River valley—the further potential for mosquito-breeding through irrigation does not necessarily affect morbidity. A study of an irrigated lowland area versus an unirrigated upland area found that participants in the irrigation scheme had a lower prevalence of malaria, in part due to the households' ability to purchase treatment because of higher income that resulted from the irrigated agriculture (von Braun 1991).

Household behavior can reduce or exacerbate the risk of malaria. One study of the Amazon region in Brazil reported that a household's likelihood of contracting malaria was decreased by greater distance of the house from the forest; use of insecticides; and improved quality of housing, water, and sanitation (Vosti 1990). One important but understudied area is the effect of irrigation on domestic water use. Irrigation can increase agricultural production and, in turn, income. Increased income can enable households to purchase rain vats or pumps that make domestic water more accessible. Improved water sources can decrease waterborne illnesses, which would improve nutrition. Here again, this is an area where further study is needed in order to fill critical information gaps.

Although the incidence of disease has increased with the expansion of irrigation, most dramatically in Africa, a lot is known about environmentally effective approaches for reducing illness. Greater awareness of disease risks has led to increasing use of field surveys to determine the likely health impacts of increased irrigation in local areas. The potential health risks must be addressed in the design phase of irrigation projects. Control over negative health effects is technically possible but requires the expertise of a multidisciplinary team including public health specialists and, in some cases, expensive treatment measures. Enough is now

known about tropical disease transmission associated with typical irrigation schemes that solutions to anticipated problems can be put forward before projects are implemented.

A recent review of health experiences in a variety of irrigation schemes reports that "perhaps the most basic lessons about control measures are that they must be implemented on a system-wide basis, must be kept in continuous operations, and cannot be chosen piecemeal from a narrow perspective of any single discipline" (Moris and Thom 1987). For instance, the fish introduced to control weed growth in irrigation canals may also serve as intermediate hosts for human parasites. The complexity of the overall ecology must be considered in designing scenarios to improve the health effects of water management projects.

COMMERCIALIZATION OF AGRICULTURE

The deteriorating economic situation in the 1980s forced many developing countries to adopt a series of macroeconomic policy reforms. A common element of these economic adjustment programs has been an emphasis on the commercialization of agriculture. Policymakers view export/cash crops as a means to generate foreign exchange, provide income-earning possibilities for the poor, and improve food security and nutrition.

Critics of the commercialization of agriculture have argued that national-level food security will deteriorate as farmers shift land from staple food crops into cash crops. However, national-level data suggest that this has not happened. An analysis of data from 78 countries indicated that countries that did well in growth of export agriculture also had positive rates of growth in staple food production (von Braun and Kennedy 1986). Appropriate policies for input supply, output marketing, and rural infrastructure benefited both food-crop and cash-crop production. Expansion of export agriculture need not be at the expense of staple-food production.

The most contentious issues in the cash-crop/food-crop debate have revolved around the impact of commercial agriculture on household food security and the nutritional status of individuals. Proponents of commercial agriculture contend that the transition from semisubsistence to a more commercialized agriculture will increase household income and, in turn, improve food intake and health and nutritional status. Critics of cash-cropping policies have argued that, in many cases, household income does not increase, but even in situations where household income improves, there can be a deterioration in food security because of shifting control of income from women to men.

A series of case studies recently conducted by the International Food Policy Research Institute (IFPRI) in The Gambia, Guatemala, Kenya, the Philippines, and Rwanda looked at the links between entry into commercial agriculture and the health and nutritional status of women and children (von Braun and Kennedy forthcoming). The five case studies used a similar protocol emphasizing the links between commercialization of agriculture and individual nutritional status as outlined in Figure 1.

Figure 1 suggests that a primary positive effect of agricultural commercialization will operate through higher incomes. Increased household income could lead to increased food consumption as well as increased expenditures to cure and prevent sickness. In addition, as a result of hiring labor for farm work and less need to seek employment outside the home, more time could be made available for nurturing behavior.

In all five case studies, The Gambia, Guatemala, Kenya, the Philippines, and Rwanda, the incomes of the more commercialized households increased; at least a portion of this increase was due to cultivation of the new cash crop. However, there was also a conscious effort on the part of smallholder farmers to maintain subsistence production along with the commercial crop, even though the returns to land and labor in most cases are higher for the cash crop than the staple crop. This appears to be the households' response to high transaction costs and market, employment, and production risks.

Similar to the findings for introduction of modern cereal varieties, entry into commercial agriculture tends to occur earlier and more often for richer farmers. A longitudinal study from Kenya found that it was the wealthier, larger landholding farmers who began sugarcane production soonest (Kennedy 1989). Once it was established that sugarcane production could be profitable, the poorer farmers entered the scheme. These new entrants had returns to land and labor that were as good as, or in some cases better than, those of the earlier participants. This is a general theme in the literature: the risk-averse, poorer farmers are late adopters but, having adopted, can profit from the innovations.

Earlier entry of smallholders could be facilitated by easier access to services. Credit is often difficult for poor farmers to obtain, and agricultural extension services are typically biased against smallholders, particularly women farmers (Staudt 1978). Government policies can relieve these and other constraints for the poor (Binswanger and von Braun 1991).

Commercialized agriculture has also resulted in increased employment (von Braun and Kennedy forthcoming); however, the employment effects are very crop- and location-specific and are a function

of the technologies introduced. Choice of crop and technology, therefore, has a major influence on the actual outcome of the employment effect. Commercialization can have a substantial effect on demand for hired labor when greater processing is involved, as compared with the traditional (often cereal) crop.

An exception to these generalizations occurred in the Philippine case study where smallholder corn tenant farms were consolidated into larger sugarcane-growing operational units that used hired labor. A substantial number of corn tenants lost access to their land and were forced to depend on agricultural wages as their main source of livelihood; these households experienced a decline in income. Overall demand for labor declined marginally. Sugarcane processing was more highly mechanized than corn processing. The larger sugar haciendas used highly mechanized production techniques, although a comparison of smallholder sugarcane and corn production showed virtually no difference in labor utilization. Nevertheless, small landowners who kept their land and who were able to obtain milling contracts made higher profits from sugarcane production than corn production (Bouis and Haddad 1990).

The generally positive income effect of cash cropping resulted in an increase in food expenditures and an increase in household calorie consumption. The impact of commercialization on food expenditures was greater than the effect on calories because households tended to purchase more-varied, higher-priced sources of calories such as meats and fruits. Higher household calorie intakes were associated with increases in the energy consumption of preschoolers. However, the increases, although statistically significant, were modest. A doubling of household income in Kenya and the Philippines resulted in an increase in preschooler energy intake of only 4 percent and 7 percent, respectively. This was in areas where the average calorie deficit in the child's diet was 20 to 30 percent below recommended levels.

Thus, quite large percentage increases in household income would be needed to fill the energy gap via the income/household calorie/child calorie link. A caveat is that the food consumption analysis was limited primarily to calories. This may underestimate the income/micronutrient impact of cash-cropping schemes.

In the IFPRI commercialization studies, it was found that increases in household income were not usually associated with a significant decrease in morbidity (Kennedy, Bouis, and von Braun 1992). This is because the poor health/sanitation environment in the study areas overshadows any potential positive effect of increasing household income on child health. The one exception was in Guatemala, where participa-

tion in an export vegetable scheme was associated with a decrease in the incidence of illness in preschool-aged children. Interestingly, the export cooperative had a health/social welfare component financed out of profits generated from the smallholders' scheme. The positive health effect was related to this rather than the increment in household income.

A three-country study in Egypt, Kenya, and Mexico reported that the morbidity-linked preschooler

malnutrition showed little response to short-term increases in income (Calloway et al. 1988). Disease patterns were the key determinant of how well a child grew in the first years of life. In order to have a dramatic influence on decreasing malnutrition in the short to medium term, agricultural policies and programs have to be promoted in tandem with health and sanitation programs in rural areas.

Time Allocation, Nurturing Behavior, and Income-Control Linkages

"It is not possible to achieve necessary changes in nutrition, health, and population growth without addressing the roles of women in these areas" (African Development Bank 1990). It is clear that women are the gatekeepers between households and individual members in decisions regarding food allocation, health, and nutrition. Agricultural and food policies and programs will have an effect on women via three main pathways: (1) women's time allocation, (2) women's income control, and (3) women's health and nutritional status.

WOMEN'S TIME ALLOCATION

Since publication of Boserup's study (1974) of women's roles in agricultural production in Africa, the relationship between the hours a woman works and how much she benefits from agricultural development policies and programs has been strongly debated. Early descriptive studies of women's labor patterns in rural communities detailed long and arduous days of back-breaking labor without the benefit of technological assistance (Staudt 1978; Dey 1985). One major way in which agricultural innovations can affect women is through the demand for women's labor. Since women are involved with both home-production activities (cooking, fuel and water collection, and child care) and agricultural production, the concern with any type of technological change is that there will be a reallocation of women's time away from nurturing activities toward on-farm labor. The degree to which this will happen depends on a number of economic and cultural factors.

In many cultures, particularly in Africa, men and women have different responsibilities for crops, labor, and support obligations of the household. Men are frequently responsible for land clearing and preparation, whereas women are responsible for other aspects

of crop cultivation. New technologies may affect the intrahousehold allocation of labor. For example, the introduction of mechanical technology for rice production in Sierra Leone slightly decreased the mean number of hours worked by men, while the amount of time required for female labor increased by 50 percent (Spencer and Byerlee 1976). In this case, the demand for men's time decreased because less time was needed for land cultivation; the demand for women's time increased dramatically because there was now additional land that could be cultivated, thus more female labor was required for planting and harvesting. Not all types of technological change work to the disadvantage of women. The introduction of biochemical technology for inland swamp rice increased the demand for men's time by 80 percent because of increased land development, but female input remained about the same (Spencer and Byerlee 1976). In the IFPRI Philippine study, where total labor inputs were nearly identical between corn and sugar and where land devoted to sugarcane production replaced land devoted to corn production, the proportion of total labor provided by adult women declined from 23 percent for corn to 11 percent for sugarcane (Bouis and Haddad 1990).

Generally, one assumes that as household income increases, individual members increase their amount of leisure and decrease hours devoted to work. If this happens, women's time burden decreases and this should have a positive effect on nutrition. However, the manner in which increased income is generated will influence the labor/leisure trade-offs. In another sugarcane-producing area, this time in Kenya, increased income was associated with a decrease in hours devoted to work only in certain kinds of households (Kennedy 1989). In male-headed and legally female-headed households, as household income increased, the energy expenditure of women decreased. However, in *de facto* female-headed households,³ as household income increased, women

³ Defined as a household whose male head is away more than 50 percent of the time.

continued to have a high level of energy expenditure. This is because much of the increased household income accrued from the increased amount of women's time devoted to on-farm (energy-intensive) income-generating tasks.

Another study in the Embu area of Kenya found that the time spent in child care was affected by the time devoted by women to food production (Paolisso, Baksh, and Thomas 1989). The authors concluded that agricultural development projects that increase the demand for women's time in crop production must address the implications for child care and other home-production activities.

Labor-saving technologies such as mechanization do not necessarily decrease the time inputs of all household members equally.

WOMEN'S INCOME CONTROL

As discussed in a previous section, the positive effect of increased income on household food consumption is well established (Alderman 1986). However, there is also evidence that the household member who controls the income and the form in which the income is received (lump sum versus continual source of payment) may also influence the effect on food consumption. Women's income, particularly in Africa, is more likely than men's to be spent on food (Haddad and Hoddinott 1991; Guyer 1980). To the extent that agricultural technologies increase not only household income but the share of income controlled by women, there is likely to be a positive effect on household food security.

A review of the IFPRI commercialization studies indicates that, by and large, cash-crop income is viewed as men's income (von Braun and Kennedy forthcoming). Women in more commercialized households did not gain in the share of income they controlled as a result of household production of cash crops. Yet, in many cases, the amount of female-controlled income exerts a positive effect on household food security. In Kenya, Rwanda, and The Gambia, the amount of female-controlled income significantly increased household energy consumption (von Braun and Kennedy forthcoming). The effect was most pronounced in the lowest income groups. If policymakers are interested in adoption of new technologies under the control of both men and women farmers, innovative methods of diffusion of the various approaches have to be developed.

WOMEN'S NUTRITIONAL STATUS

The health and nutritional status of women is one of the prime determinants of child nutritional

status. Birth weight is the single biggest factor influencing neonatal and child mortality and child growth up to the age of seven. A number of maternal factors, including preconception weight and weight gain during pregnancy, are known to affect birth weight. To the extent that either preconception weight or pregnancy weight gain can be positively affected, birth outcomes will improve.

Unfortunately, many women begin pregnancy underweight and have limited weight gains during pregnancy. In developed countries, the typical weight gain during pregnancy is 10-12 kilograms; in developing countries, it is 2-7 kilograms (Ghassemi 1990). In many developing countries, negative weight gains during pregnancy are common. Part of the reason for inadequate weight gain is the tendency to maintain a constant food intake, or in some cases even to decrease the amount of food consumed. This last phenomenon has been labeled "eating down" during pregnancy (Brems and Berg 1988).

While the conscious effort to limit calorie consumption during pregnancy is practiced by some women, in many areas of the developing world it is the high level of physical activity, uncompensated for by additional calories, that is the more common reason for low weight gain. For example, in The Gambia birth weights were below average only after the peak period of agricultural labor (Lawrence and Whitehead 1988); during nonpeak seasons, birth weights were close to international norms. These data imply that when agricultural labor demands are high, pregnant women are unable to compensate by increasing their food intakes.

Morbidity during pregnancy has been correlated with a higher incidence of low birth weight (less than 2,500 grams). In Guatemala, researchers found that women with high rates of infection during pregnancy tended to come from households with low caloric availability (Lechtig et al. 1974).

Dietary supplementation schemes targeted to high-risk women can be effective in improving birth outcomes. However, this type of intervention has had limited success on a large scale; irregular participation of women is a major factor limiting effectiveness. Poor attendance at supplemental feeding sites is caused by the women's lack of time. A more promising approach to improving neonatal outcome is to decrease physical activity, particularly during the last trimester of pregnancy. For example, in the Mindanao area of the Philippines, women in higher-income, sugarcane-growing households were able to decrease the amount of physical activity in the last trimester of pregnancy (Bouis and Kennedy 1989). This was associated with higher weights and heights of infants born to women in sugarcane-producing households compared with corn-producing households.

To the extent that household adoption of agricultural technologies can decrease women's workload, including that of pregnant women, the approach affords the potential of high payoffs to the

nutritional status of the newborn and the mother. Any intervention designed to improve women's nutritional status must take into consideration the women's time constraints.

Nutrition as an Input into Agriculture

The discussion thus far has concentrated on looking at indicators of nutritional status as outcome measures of development policies. One can also view nutritional status as an input into agricultural growth. A common assumption is that better-nourished individuals will be more productive. Until recently this premise was based more on theory than empiricism.

A number of recent studies have established the links between improved consumption and productivity (Sahn and Alderman 1988; Strauss 1986) and between better nutritional status and productivity (Deolalikar 1988; Haddad and Bouis 1991). Because of data limitations, most of these studies were limited to adult males. Research on women farmers in Kenya reports some similar relationships; women's nutritional status (as measured by Body Mass Index) in 1984 was a significant predictor of total energy expenditures in the following 1985-87 study period. Better-nourished women were able to put more time into nonleisure activities.

Technologies that can lead to improved nutritional status can enhance the success of agricultural programs. Few studies have looked directly at adult nutrition as an outcome measure of agriculture. A recent multicountry review suggests that the economic losses due to reduced labor productivity are

\$8.7 billion annually (Pinstrup-Andersen et al. 1991).

Strategies that increase the incomes of the poor—by whatever means—will increase their food consumption, particularly consumption of nonstaple foods. The majority of the poor, and thus the food insecure, are in the rural areas of developing countries. An increased emphasis on agricultural investments and programs that reach the food insecure offer an effective means of reducing food insecurity at the household level.

However, the influence of technological change and commercialization on women and children is more diffuse than the household-level effects. Large gaps in knowledge exist with regard to the effects of agricultural policies on health and nurturing. In the few studies that have been done to date, income-generation at the household level does little to significantly improve child morbidity patterns or nurturing behavior in the short to medium term. Thus a neutral association between technology and health/nurturing of children is suggested in most cases (Table 1). Future efforts linking nutrition concerns more directly to agricultural policies and programs need to concentrate not only on production/consumption effects but health/nurturing effects as well. Examples of how this might be done are given in Chapter 7.

Table 1—Summary of agriculture/nutrition effects

Innovation	Household-Level Effects			Individual Household Member Effects				
	Agricultural Production	Income	Employment	Preschoolers ^a			Women	
				Food	Health	Care	Income	Time
Technological change in inputs	+ to ++	+	+	+	I	- to 0	0	- to 0
Irrigation	+ to ++	+	+	+	- to 0	- to 0	0	- to 0
Commercialization of agriculture	+ to ++	+	+	+	0	0 to +	0	- to 0

Note: + = positive
 ++ = very positive
 0 = neutral
 - = negative
 I = indeterminate

^a Preschoolers are defined as children from birth to six years of age.

Recommendations for Future Research

Great progress has been made since the 1950s in dealing with problems of hunger, in large part because of agricultural research that has resulted in improved agricultural technologies. Technological change in agriculture has markedly reduced poverty in Asia; its effects have been direct, through increased agricultural employment, as well as indirect, through low food prices and increased nonagricultural employment stimulated by increased farmers' incomes.

Despite such breakthroughs, food insecurity and malnutrition remain problems for a large number of people throughout the world. Agricultural policies and programs will continue to have a critical role in addressing the problems of both food security and nutrition. To achieve food security and adequate nutrition, actions must be taken at the international, national, community, and household levels.

The theme running through this paper is the possibility of identifying ways to achieve nutrition objectives via agricultural policies, programs, and projects. This identification needs to be done in a way that does not create the expectation that the agricultural sector will become a substitute for primary health care delivery. Clearly, it will not. However, given what appears to be the continuing problem with health care service delivery in rural areas, maximizing the nutrition effects of agricultural policies, programs, and projects already in place seems to be an attractive alternative for improving nutrition.

The idea of linking food security and nutrition goals with agriculture is not new. Ten years ago, this issue was highlighted. Effective approaches for incorporating nutrition goals into agricultural and rural development projects were recognized as necessary, but the effective approaches for doing so in an operationally acceptable way were not available (Pinstrup-Andersen 1981). A lot has been learned since then; donors and policymakers can capitalize on this experience.

INTERNATIONAL LEVEL

Investment in agricultural research must increase. Sustaining the gains that have been made in agricultural productivity and extending agricultural technologies into untouched areas will depend on continued support for agricultural research. This need occurs at a time when support for the international and national agricultural research centers is plateauing or declining.

As already discussed, the net effect of the technological innovations of the 1970s and 1980s was that, for the developing countries as a whole, food supplies increased more rapidly than population growth. This needs to be maintained in areas where it has succeeded and extended into areas where technology has had less of an effect. However, it will not be easy. Over the coming decades, the global population is expected to increase by 90 million people per year, with 95 percent of this increase occurring in the developing countries of Africa, Asia, and Latin America (Kennedy and Haddad 1992). Many developing countries are experiencing a shrinking agricultural resource base on which to feed their growing populations.

At the global level, growth rates in crop yields are declining. There is less scope to increase the land area cropped in order to compensate for the falling production. Efforts to overcome these constraints often degrade the environment and conflict with the longer-term sustainability of agriculture (Vosti, Reardon, and von Urff 1991). The relentless pressure to increase food production to keep pace with population growth has forced many countries to accept short-term solutions that ultimately threaten the sustainability of initial food production gains. Some of these solutions, such as increased fragmentation of landholdings or expansion of cultivated land into ecologically fragile areas, are compounded by the effects of encroaching urbanization and deforestation. It is estimated that 6-7 million hectares of agricultural land in developing countries are made unproductive each year because of soil erosion.

Waterlogging, salinization, and alkalization from irrigation damage another 1.5 million hectares (Vosti, Reardon, and von Urff 1991).

Of all the developing regions, Africa faces the most alarming prospects. With an annual population increase of 3 percent—unprecedented in history for an entire continent—per capita food production has declined to the point that Africa has ceased to be a net exporter of food staples. It is paradoxical that in a continent where more than 75 percent of the population is engaged in smallholder food production, over 20 percent of food staples consumed are imported, and this percentage is rising. If current production growth trends continue, food output in Sub-Saharan Africa alone could fall short of projected demand by almost 50 million metric tons by the year 2000.

The situation in Asia is somewhat brighter in that population growth rates have fallen as incomes have increased in a number of countries; real cereal prices have fallen as production has kept ahead of population growth. However, Asia, home to over half the world's population and producer of over 90 percent of its rice, currently has an estimated 82 percent of its potential cropland already under production. Thus, new yield-increasing technologies must be found.

The food availability statistics for Latin America as a whole are positive. However, gains in food supplies have not been uniform across the region. While the gains in energy consumption were positive for the region as a whole for the period 1960-85, the Andean countries (Bolivia, Ecuador, and Peru) and the Southern Cone countries (Argentina and Chile) had a negative rate of growth in energy consumption (Campino and Kennedy 1989).

Technological change in agriculture will continue to be the most promising route for raising food production. However, this second wave of the green revolution will involve approaches that are different from those of the past. As new land becomes less and less available, increased agricultural production will depend more on yield-increasing strategies than on expansion of cultivated area. FAO (1986) estimates that over the next decade less than 20 percent of production increases will come from area expansion; the bulk of food production growth will come from yield increases and multiple cropping in irrigated areas. Small-scale irrigation projects with very active local participation have been shown to be effective, sustainable, and environmentally viable. More attention will be focused on these types of schemes as a way to expand water supply.

The modern, high-input technologies have not been universally adopted. In many areas, a low-input system may be more viable. Crops that have received relatively less attention in the past—millet,

sorghum, roots, and tubers—may become more important in agricultural research.

Given the diverse concerns just highlighted, the following areas for agricultural research should be given high priority.

Sustainable Agriculture. Meeting the food demands for the developing world will continue to require investment in agricultural research. This will require development of yield-increasing technologies that increase agricultural production in an environmentally sound manner. To this end, the whole area of management of natural resources (soil, forests, water, and biodiversity) needs to be given greater attention. As part of this new research thrust, researchers must also give attention to new yield-increasing technologies that do not disrupt the health environment.

Biotechnology. Biotechnology in animal and plant breeding is an area with a huge potential for increasing food supplies. Breeding of new disease-resistant seeds and seed varieties adapted for arid and semi-arid areas are some examples. However, most of the biotechnology research to date has been conducted in the private sector. Few attempts have been made to bring this research to developing countries. Insights gained from private-sector research in biotechnology can improve the quality of publicly funded research. In order to transfer this technology from the private to the public sector there must be a forum to discuss these new techniques and methods of transfer. International organizations can help facilitate this interaction of public and private research groups.

Specificity to Agro-ecological Region. The production-increasing technologies that will be developed will require ongoing research related to the specific needs and constraints of the different agro-ecological zones in developing countries. In Africa, with the widest variety of agricultural zones, much more adaptive research on yield-increasing technologies must be done.

Diversification. Agricultural research directed toward diversification in crop production including fruits and vegetables, livestock, fishery, and agriculture should be encouraged. A diversified cropping strategy may help eliminate much of the seasonality in production and consumption as well as the concomitant negative effects on nutrition.

Multicropping Systems. Environmentally sound multicropping systems are needed to meet the dual

goals of increasing crop production and maintaining soil quality.

Postharvest Crop Preservation. Technologies that can decrease postharvest crop losses caused by spoilage and rodent infestation need to be developed.

Women's Time Allocation. It is important to ensure that the adoption of technologies does not increase the time burden of women.

Extension Services. Ways need to be developed for using extension services to facilitate community participation in identifying research needs of farmers and consumers.

Training. Training methods at the international, national, and local levels need to be developed to ensure dissemination of new technologies.

Agricultural Research and Public Policy. The review in this paper has shown that the absence of technical solutions is not the only constraint to improving food security and nutrition. Much more attention needs to be focused on the links between agricultural research at the international level and the means of translating this research into public policy at the national and community levels. The continual failure of researchers to understand how governments, communities, and households would react to innovations in agriculture has been a major bottleneck to adoption and success of potentially useful approaches for improving nutritional status. This is not a problem that is unique to nutrition but it nonetheless needs to be addressed.

NATIONAL LEVEL

Coordination of Agricultural and Health/Sanitation Projects

Agricultural programs do not in and of themselves enhance the overall health and sanitation environment, and as shown by the examples of irrigation projects discussed previously, they may result in a worsening of the health and sanitation environment. Many policymakers assume that the general economic growth that occurs as a result of growth in the agricultural sector will contribute to increased allocation of national income to primary health care and other social services. However, basic services such as access to safe water do not show a close relationship to national per capita income levels (von Braun 1991). Thus, one cannot

assume that agricultural growth will necessarily translate into improvements in the health and sanitation environment.

At the same time, however, it needs to be recognized that successful agricultural projects that increase the incomes of the rural poor are difficult and complex undertakings in themselves, without the added burden of incorporation of an integrated health or sanitation improvement program or both. Administrative structures and arrangements are needed to spawn projects and policies that exploit the complementarities for better nutrition between increased rural incomes and an improved health and sanitation environment, but that allow agricultural and health ministries to act as independently as possible.

Macroeconomic Price and Investment Policies

A distorted set of macropolicies—which may include an overvalued exchange rate or subsidized interest rates—makes rapid growth in agricultural output extremely difficult (Timmer, Falcon, and Pearson 1983). While such policies often benefit poor urban residents in the short run in the form of low food prices, over the long run they are harmful to nutrition, since they inhibit long-term economic growth and eventually force (sometimes abrupt) reforms that can have painful consequences for the poor through unemployment, higher food prices than might otherwise have been necessary, and lower investments in the health and sanitation infrastructure.

For example, an overvalued exchange rate allows manufactured imports to enter the country relatively cheaply, thus lowering the input costs and raising the profits of industrial producers, while lowering the profits of producers of agricultural exports. Not only will manufacturing production eventually stagnate because industrial producers will not be able to compete internationally in such an artificial price environment, but the overvalued exchange rate acts as a tax on agriculture so that rural economic growth is inhibited as well.

Such macroeconomic policies are symptomatic of a general tendency toward policies that are biased toward urban areas. Investments in infrastructure for direct economic purposes such as roads and communications facilities and for health and sanitation are often disproportionately located in urban areas. Such price distortions and policy biases at the national level against agriculture, and against rural areas more generally, should be removed in order for investments in agricultural research and increased food production to meet the objectives of higher rural incomes and low food prices that can be sustained over the long run.

HOUSEHOLD LEVEL

Policy research will need to continue to focus on a better understanding of how household behavior responds to government policy. The links between income-generating policies and programs, poverty alleviation, and improved household food intake are clear. Strategies that increase the incomes of the poor will result in significant reductions in hunger. This is hardly surprising. However, although the household income/food security links are strong, the links between income and improvement in nutritional status are less robust. Evidence reviewed in this paper suggests that income-generating schemes by themselves may be insufficient to alleviate malnutrition, at least in the short to medium term (von Braun and Kennedy forthcoming; Kumar and Alderman 1989; Alderman and Garcia 1990). Thus, policymakers need to explore ways to improve the food security and nutrition impact of income-generating policies, such as the range of agricultural policies and programs that are being implemented in developing countries throughout the world.

Some common elements appear to be associated with agriculture/nutrition approaches that have reported success in achieving either food security or nutrition goals or both (Kennedy 1991). First, agriculture/nutrition interventions are more likely to succeed if they are implemented through the existing infrastructure and through existing programs. A recent inventory to catalog the range of agricultural policies and programs used to achieve food security and nutritional objectives in Asia, Africa, and Latin America revealed that five categories of policies and programs were most common: cash-crop production; use of hybrid seed varieties; agricultural extension; credit; and use of improved, low-technology food crop production techniques (Kennedy and Payongayong 1991). There was a remarkable similarity in the types of programs implemented. Within the context of these five areas, policymakers should explore ways to better address nutrition concerns.

Second, within the range of agricultural policies and programs being employed in developing countries, the ones that have consistently demonstrated a significant impact on nutrition are those that combine an emphasis on increasing household income with health/sanitation/education activities directed toward the intrahousehold allocation of resources (Kennedy 1991; Kennedy and Alderman 1987). Attention to income generation within the household in conjunction with approaches that decrease the time burden of women seems to be particularly important.

Examples of some prototype agriculture/nutrition approaches are given below.

Cash-Crop Production Schemes That Include Health/Social Services. In the recent comparative analysis of cash-cropping projects in six countries—Gambia, Guatemala, Kenya, Malawi, Philippines, and Rwanda—participation in the cash-crop cooperative was associated with a decrease in the incidence of illness only in Guatemala. The health/social services activities that were provided to cash-cropping households were financed from profits generated from the Guatemalan cooperative. It would be useful to look at a similar approach in other projects to determine the elements that contribute to improved health, and so to improved nutrition in conjunction with increased incomes.

Agricultural Extension Targeted to Women. Agricultural extension is typically a large part of the agricultural sector budget in most developing countries. Yet extension activities typically have not done very well in reaching rural women. Since women are actively involved in food crop production, extension activities geared to women could result in increased food production that would benefit household food security as well as increased women's income that would lead to improved child nutrition. Ways to use extension to reach women need to be tested. Zimbabwe has given priority to extension services targeted to women. Agricultural services emphasizing women could be evaluated and compared with the more traditional types of extension services.

Cropping Strategies That Decrease Seasonality. Increased agricultural labor demands, particularly for women, often coincide with periods of household food shortages and peaks in levels of illness. Smoothing out seasonal cycles in production, consumption, and labor has a potential benefit for household food security and nutrition.

Credit for Women in Rural Areas with Nutrition Activities. Credit schemes that use participatory and social marketing techniques to develop nutrition activities offer the potential of increasing women's income and building on nurturing behaviors that will improve child nutrition. An example of this type of approach is the ongoing credit/nutrition project in Mali.

CONCLUSION

Government policies must continue to concentrate on raising the incomes of the rural poor and on

keeping food prices low by increasing food production. Past investments in agricultural research and infrastructure (including irrigation) and increased commercialization have done much to improve nutrition among the poor, but malnutrition is still widespread. Because population continues to grow, it is imperative that these high-payoff investments continue to be made. Macroeconomic and trade policies that are biased against agriculture reduce the beneficial impacts of these investments and so need to be eliminated. These production- and income-related linkages with nutrition have been relatively well researched and are relatively well understood, although more work is needed in evaluating the factors that influence intrahousehold distribution of resources, especially as they relate to women's control of income, women's decisionmaking power within the household, and women's health and nutrition.

High morbidity rates in rural areas significantly diminish the potential nutritional benefits of higher household income and lower food prices. What evidence is available suggests that raising household incomes alone does not significantly reduce morbidity. Although some research results are now available and other research is already in the pipeline, it is not yet clear what types of health interventions will have the highest payoffs. Deficiencies in vitamin A, iron, and iodine intakes, which are more important than once thought, may be remedied through fortification, supplementation, or nutrition education in conjunction with increased household income. Much needs to be done to improve community-level health and sanitation and to increase the availability of medical services, including preventive care such as provision of immunizations.

Most policymakers and donors would agree that all of these health-related investments improve welfare, but they compete for scarce resources that might otherwise be used in agricultural research and infrastructure development to increase food production. A critical question, then, is whether poor health and nutrition constrain agricultural productivity at the level of the individual household farm. In

the case of major illnesses, to what extent does the need to pay for medical care eliminate savings (or create debt) that might have been used instead to invest in land improvements, livestock, and other agricultural inputs? Even for minor illnesses, what are the short-run costs of reduced labor productivity if, as is often the case, adults work while sick, or of lost work time both for recuperation and for taking care of sick household members? What are the long-run effects of ill health on reduced capacity for work and cognitive ability of children? Much research is still needed to measure the magnitude of these problems, to evaluate the economic returns to specific health-related programs and policies, and so to convince skeptics that such investments are vital inputs into overall development.

A high-input agricultural production strategy based on fertilizer-responsive crop varieties, which in many instances are highly dependent on irrigation, is necessitated by population growth and a constrained land base. Such a strategy reduces migration to and cultivation of environmentally more fragile upland areas, relative to a low-input strategy. Nevertheless, critical questions remain not only as to the sustainability of such a strategy in terms of maintaining soil fertility but also as to detrimental health effects. Establishment of large-scale irrigation projects may introduce schistosomiasis and other debilitating diseases. Populations become exposed to harmful chemical inputs, both through direct contact and indirectly through the water and food chains.

To what extent are high morbidity rates in rural areas a direct outcome of the chosen agricultural development strategy? To what extent are these high morbidity rates exacerbated by higher population densities? It is these types of environmental-health linkages, about which the least is known, that lend a sense of urgency to research in this area. Even though some studies have been reviewed here and additional data are being collected, further conceptualization work is still needed to answer these questions in a fully satisfactory manner. This work is made more difficult because it will necessarily require interdisciplinary cooperation.