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Agricultural Research and Poverty Reduction

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Foreword

International agricultural research has contributed enormously to increasing world food supplies to their current state of plenty. Yet poverty remains a major problem and the challenge for agricultural research now lies in developing strategies that more explicitly address the needs of the poor. This paper, based on the study commissioned by the Technical Advisory Committee (TAC) of the CGIAR system, addresses this issue.

Based on an analysis of the links between agricultural research and poverty alleviation in different types of countries and rural regions, Peter Hazell and Lawrence Haddad identify six key priorities for a pro-poor agricultural research agenda: (1) increasing production of staple foods in countries where food price effects are still important and/or that have a comparative advantage in growing these crops; (2) increasing agricultural productivity in many less-favored lands, especially heavily populated low-potential areas; (3) helping smallholder farms across the board diversify into higher value products, including livestock products, especially in countries with rapidly growing domestic markets for such products and/or access to suitable export markets; (4) increasing employment and income-earning opportunities for landless and near-landless workers in labor surplus regions; (5) developing more nutritious and safer foods to enhance the diets of poor people; and (6) undertaking agricultural research in ways that are more empowering to the poor.

Hazell and Haddad discuss strategies for achieving each of these goals with the least trade-off in national agricultural growth. In short, Hazell and Haddad suggest strategies to target agricultural research on poor peoples' problems in ways that are "win-win" for growth and poverty reduction.

Although the rates of return to public agricultural research are known to be high, public funding for agricultural research has nevertheless declined, especially in developing countries. Yet more is being asked of agricultural research and extension systems. If new technologies and research paradigms are to be developed that specifically address the needs of the poor, then funding for international and national agricultural research must be increased.

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1. Introduction*

Until recently, researchers and policymakers saw poverty alleviation as a subsidiary goal of agricultural research. The primary goal was to increase food supplies through cost-reducing technological changes that would lead to lower food prices. Research focused on increasing the yields of important food staples in irrigated and high-potential rainfed areas, where researchers perceived the productivity returns to agricultural research to be highest. This strategy was enormously successful and led to real benefits for the poor as well as for societies in general. But it was not sufficient to eliminate rural poverty, which abounds even in countries that now have national food surpluses.

Plentiful global food supplies and declining trade barriers have created the opportunity to develop explicitly pro-poor research strategies for the public sector. The opportunity is enlarged to by the private sector's increasing role in addressing mainstream productivity challenges. Private-sector involvement seems likely to grow as the evolution of biotechnology and intellectual property regimes redefine the traditional public-goods nature of much agricultural research. Although food supplies must double over the next 20 years, increasing productivity alone will not be enough. The public sector will also need to focus sharply on the changing nature of market failures that it has traditionally sought to correct and on the growing importance of countries' other social and environmental goals. This shift will require the public sector to invest in ways that offset the private sector's

chronic underinvestment in research for poor farmers and regions and for containment of environmental problems.

Against this backdrop, what can public agricultural research systems that serve developing countries do to increase the poverty-reducing impact of their investments? This paper addresses that question generally in the Introduction. Chapter 2 examines the changing nature and extent of poverty, and its implications for agricultural research. It notes the evolution in thinking about poverty beyond measures of physiological deprivation (an inability to meet basic material needs) to incorporate measures of social deprivation (poor access to the components of power such as decisionmaking processes, information, and authority). Chapter 2 also shows the shifts in poverty rates and numbers from a spatial point of view.

Chapter 3 reviews how agricultural research can reduce poverty not only through traditional pathways (such as own-farm productivity increases, greater employment, general equilibrium effects, and the lowering of food prices), but also through newer pathways (such as community empowerment through collective action for natural-resource management). Chapters 2 and 3 suggest the need to tightly target agricultural research.

Chapter 4 outlines one possible typology to help do so. The typology was developed for potential technology-adopting regions within countries and is based on two country criteria (low- versus middle-income country and liberal-

*This paper is based on the TAC-commissioned study, which is still under review by TAC. Consequently, the paper represents a work that is in progress.

ized versus unliberalized market and trade policies) and four region-specific characteristics (high versus low agricultural potential; good versus poor infrastructure, service provision, and market access; low wages and abundant labor supply versus high wages and scarce labor supply; and whether the region's poor are empowered or disempowered in terms of access to land, other resources, and public services).

Chapter 5 describes the six pro-poor research priorities that emerge from the typology and considers research strategies for achieving them, emphasizing strategies to minimize trade-offs against sectorwide agricultural growth, which is

key to long-term poverty reduction. The six priority areas for pro-poor research are: (1) maintaining growth in staple food production, particularly in countries where food-price effects are still strong; (2) intensifying less-favored lands; (3) helping smallholders to diversify into higher value products; (4) increasing employment and income opportunities for landless workers; (5) increasing the access of the poor (especially poor women) to foods rich in crucial micronutrients; and (6) undertaking agricultural research in ways that are more empowering to the poor.

Chapter 6 concludes with recommendations for the public sector's future research agenda.

2. The Nature and Extent of Poverty

Defining Poverty

A consensus is emerging around the view that poverty consists of two interacting deprivations—physiological and social. Physiological deprivation describes an inability to meet or achieve basic material and physiological needs and can be measured either as a lack of income, which limits access to food and to education, health, housing, water, and sanitation services, or by the failure to achieve desired outcomes, such as a high-quality diet rich in micronutrients, health status, educational attainment, and the quality of health, water, and sanitation services received. Diet quality is crucial to individual well-being, particularly for girls, women, and infants.

Although income and achievements correlate, they do not do so perfectly. For example, households with relatively high-income consumption levels often contain individuals who do not get enough of the right type of food to stave off hunger, anemia, goiter, or death. This can occur because of lack of information (for example, household leaders do not realize the value of girls' education or do not know that their daughters' diets are low in iron), preferences (there may be a deliberate bias toward education for boys at the expense of girls), or an inability to use income to purchase inputs required for well-being (for example, sanitation services that cannot be purchased in the market).

Measures of physiological deprivation are relatively easy to quantify at the household level in ways that are consistent over time and across space. For this reason, usable data series have been constructed for most countries to form the

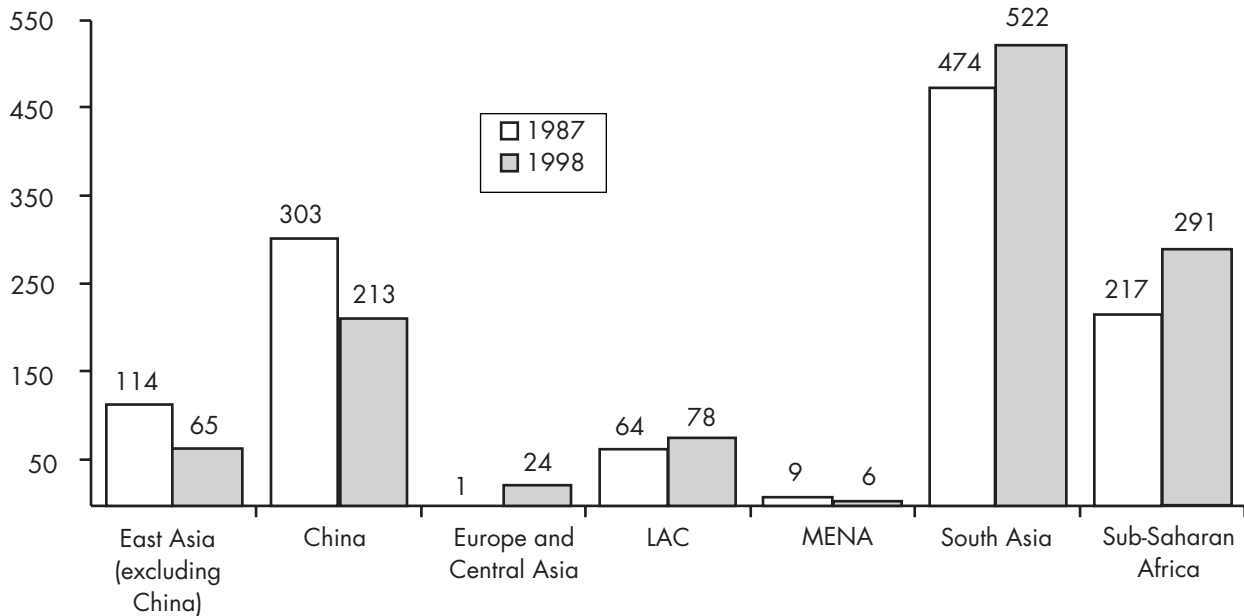
basis for international comparisons and trends analysis. Income and consumption measures are usually preferred, but nutrition indicators based on the height and weight of young children are often used as simpler measures of physiological deprivation.

Social deprivation typically is assessed at the individual or community level; it refers to an absence of elements that are empowering—autonomy, time, information, dignity, and self-esteem. Lack of empowerment is reflected in exclusion from important decision-making processes, even when the outcomes are of considerable importance to the poor—for example, decisions about public investments in the local community, management of common properties, and priorities for agricultural research and extension. Physiological and social deprivations interact in a vicious/virtuous cycle, with increased empowerment leading to greater income-earning ability, which leads to greater power, and so on. This more comprehensive social definition of poverty provides richer insights into the process of becoming poor, staying poor, or becoming less poor. It also provides an opportunity for input from the poor themselves, in terms of the dimensions of deprivation identified and the way in which severity is assessed. This input can be gained through participatory research methods.

Because measures of social deprivation are in their infancy and are based largely on qualitative analysis, quantitative indicators that are consistent over time and comparable across regions and countries are not available to describe the extent and location of poverty around the world, which this report attempts to

Figure 1—Number of people living on less than \$1 a day, 1987 and 1998

Millions of people



Source: World Bank 2000.

Note: LAC = Latin America and the Caribbean; MENA = Middle East and North Africa.

do. But where qualitative assessments have been undertaken, they provide a richer understanding of the nature of poverty and of poor peoples' livelihood strategies. Such information can be crucial to guide decisions about the design and targeting of agricultural research that meshes with the livelihood strategies of the poor. Public agricultural research systems may need to invest in collecting this kind of information in important target regions.

Poverty Trends

Poverty continues to be a major problem in many parts of the developing world. Approximately 1.2 billion rural people live in poverty (defined as living on less than \$1 per day), and about 160 million preschool children are malnourished (World Bank 2000; Pinstrip-Andersen, Pandya-Lorch, and Rosegrant 1997). Infant malnutrition rates reliably measure deprivation, given their comparabil-

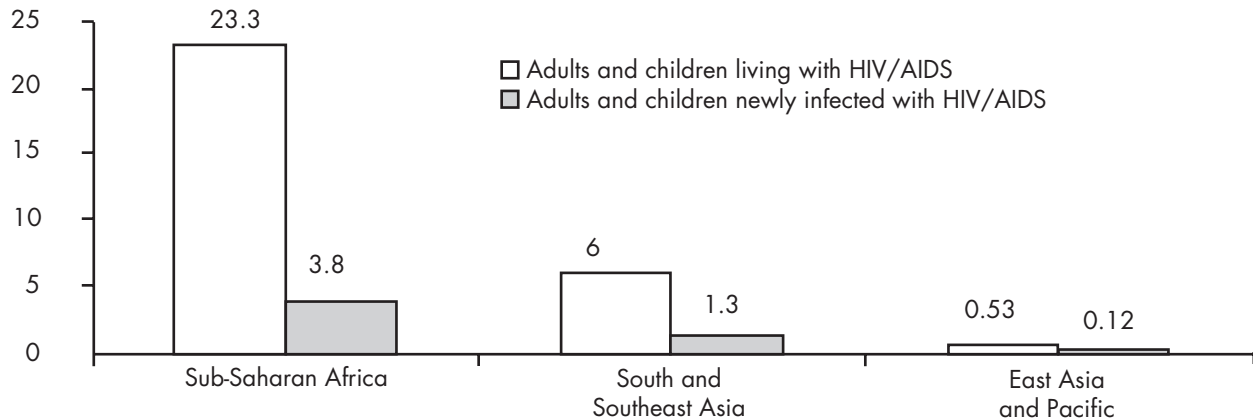
ity across space and time. These rates also are reliable lead indicators of poverty because malnutrition at a young age leads to the early onset of poor physical and cognitive productivity and to higher rates of noncommunicable diseases such as diabetes and heart disease later in life (ACC/SCN 2000).

Globally, about 90 percent of the developing world's poor live in either Asia or Sub-Saharan Africa (Figure 1). Asia dominates, with two-thirds of the total poor, who are concentrated in South Asia (43 percent). Less than 1 percent of the poor live in the Middle East and North Africa (MENA), and about 7 percent live in Latin America and the Caribbean (LAC).

The total number of poor has changed little since 1987, but the regional distribution has changed, with poverty declining in China, East Asia, and MENA but increasing in South Asia and Sub-Saharan Africa. Poverty is growing the fastest in Sub-Saharan Africa, where it is aggravated by a higher incidence of HIV/AIDS infection (Figure 2).

**Figure 2—Those living with HIV/AIDS and those newly infected:
Asia and Sub-Saharan Africa, 1999**

Millions of people



Source: www.unaids.org/hivaidsinfo/index.html

The incidence and distribution of malnourished (underweight) children of preschool age shows a similar pattern (Table 1). Most of the developing world's malnourished children live in South Asia or Sub-Saharan Africa (together accounting for 70 percent), again with the majority concentrated in South Asia (51 percent). About 49 percent of all preschool children in South Asia are malnourished, compared with 31 percent in Sub-Saharan Africa and 23 percent in East Asia (including China). Trends in the number of malnourished preschool children also show similar patterns to monetary measures of poverty. While the number of underweight children in South Asia has slowly declined, the number in Sub-Saharan Africa increased from 25.7 million in 1990 to 31.4 million in 1995. In the past five years, the situation in Eastern and Southern Africa has continued to deteriorate, spurred in part by the HIV/AIDS epidemic (ACC/SCN 2000).

Of the total number of poor people living below \$1 per day, 75 percent, or 0.9 billion, live and work in rural areas (IFAD 2001). The rural poor are distributed across regions in much the

same pattern as the total poor. A significant percentage of the rural poor live in less-favored areas that are challenged by difficult agroclimatic conditions, such as poor soil, low and unstable rainfall, steep slopes, and short growing seasons and/or inadequate infrastructure and support services (roads, irrigation, markets, research and extension, credit, schools, and health centers). According to a report by the Technical Advisory Committee (TAC) of the Consultative Group on International Agricultural Research (CGIAR/TAC 2000), "favored" agricultural lands account for only 10.7 percent of the agricultural area in the developing world and for 8.5 and 16.6 percent, respectively, in Sub-Saharan Africa and Asia (Table 2). Moreover, only about one third of the rural population live in favored lands (Table 2). The vast majority of rural people live outside these favored lands, which in the TAC study comprise "marginal" lands (24 percent of the total agricultural area), sparsely populated arid lands (26 percent), and forest and woodlands (40 percent). Some of these less-favored lands have good agricultural potential, particularly where roads and irrigation are available, so it cannot be concluded

Table 1—Trends in child malnutrition in developing countries, by region, 1970–95

Region	1970	1975	1980	1985	1990	1995	Change, 1970 to 1995
	Percent						Percentage points
Percent of children malnourished							
South Asia	72.3	67.7	63.7	61.1	53.4	49.3	-23.0
Sub-Saharan Africa	35.0	31.4	28.9	29.9	28.8	31.1	-3.9
East Asia	39.5	33.3	30.0	26.5	23.5	22.9	-16.6
Near East and North Africa	20.7	19.8	17.2	15.1	n.a.	14.6	-6.1
Latin America and the Caribbean	21.0	17.0	12.2	10.6	11.4	9.5	-11.5
All regions	46.5	41.6	37.8	36.1	32.3	31.0	-15.5
Number of children malnourished							
	Millions						
South Asia	92.2	90.6	89.9	100.1	95.4	86.0	-6.2
Sub-Saharan Africa	18.5	18.5	19.9	24.1	25.7	31.4	+12.9
East Asia	77.6	45.1	43.3	42.8	42.5	38.2	-39.4
Near East and North Africa	5.9	5.2	5.0	5.0	n.a.	6.3	+0.4
Latin America and the Caribbean	9.5	8.2	6.2	5.7	6.2	5.2	-4.3
All regions	203.8	167.6	164.3	177.7	176.7	167.1	-36.7

Source: Smith and Haddad 2000.

Notes: A child under five (0–59 months) is considered malnourished if the child falls below an anthropometric cut-off of –2 standard deviations below the median weight-for-age Z-score of the National Center for Health Statistics/World Health Organization international reference. n.a. is not available.

that the remaining two-thirds of the rural population all live in low-potential areas.

Although reliable poverty data by land type do not exist for most countries, more precise data do exist for India and China. A recent IFPRI study reports that for India in 1993, 42 percent of the rural poor lived in low-potential rainfed areas, while 16 percent lived in irrigated areas and 42 percent lived in high-potential rainfed areas (Fan and Hazell 2000). A similar share of China's rural poor lives in low-potential areas (Fan et al. 2000).

Additional insights into the distribution of rural poverty by land type are available from data on

child malnutrition. Sharma et al. (1996) have mapped the incidence of malnutrition among preschoolers by the agroecological zones defined by CGIAR (Table 3). Their analysis shows that the incidence of child malnutrition is highest in warm, semi-arid tropical and subtropical areas (zones 1 and 5) and that 43 percent of all malnourished preschool children live in these areas. Food production per hectare is also relatively low in these zones despite average or above-average levels of irrigation.

The rural poor are predominantly smallholder farmers and landless agricultural workers. For the

Table 2—Distribution of land types by region

Region	Land type (% of total land)				Rural population living in favored lands (%)
	Favored	Marginal	Sparsely populated arid lands	Forest and woodland	
Sub-Saharan Africa	8.5	23.1	24.6	43.7	27.0
Asia	16.6	30.0	18.5	34.6	37.0
Latin America and Caribbean	9.6	20.3	8.1	61.9	34.0
Near East and North Africa	7.8	22.6	65.8	3.9	24.0
Total (105 countries)	10.7	24.0	25.9	39.4	35.0

Source: CGIAR/TAC 2000.

Table 3—Distribution of malnourished children by agroecological zone, 1990

Agroecological zone	Malnourished children		Food production/ hectare of arable land (TGE)	% of arable land irrigated
	Millions	% of total children		
1. Warm, semi-arid tropics	47.9	49.0	0.98	17.2
2. Warm, sub-humid tropics	20.6	36.4	1.03	9.3
3. Warm, humid tropics	38.0	37.0	1.92	18.2
4. Cool tropics	8.1	26.0	1.50	8.3
5. Warm, semi-arid subtropics (summer rainfall)	31.7	44.0	1.07	40.0
6. Warm, sub-humid subtropics (summer rainfall)	7.4	38.0	1.44	26.8
7. Warm/cool humid subtropics (summer rainfall)	10.4	19.0	1.41	21.3
8. Cool subtropics (summer rainfall)	10.6	23.0	1.28	14.6
9. Cool subtropics (winter rainfall)	8.2	17.4	0.78	23.2
Total	183.4	33.7	1.20	20.0

Source: Sharma et al. 1996 (Table 2).

Note: TGE = total grain equivalent.

developing countries as a whole, about half the rural population lived in smallholder farm households in 1988, and one-quarter lived in landless labor households (Jazairy et al. 1992). The ratio of landless to smallholder farmers was much lower in Sub-Saharan Africa (0.15) than in Latin America (0.82) or Asia (0.53).

Smallholder farms are getting smaller and more numerous in most parts of the developing world (Hazell, Jagger, and Knox 2000). This contrasts sharply with changes in the industrialized countries where farms are getting larger and there has been an exodus of small-scale farmers from agriculture.

Smallholder households are also diversifying their livelihood strategies and increasing their share of nonfarm income (Reardon et al. 1998; Carney 1998). Smallholders and landless workers typically earn more than half their total household income from nonagricultural sources. Such diversification could reflect worsening impoverishment and desperation as land becomes increasingly scarce, or it could reflect increasing prosperity, as rural workers are attracted to higher-paying nonfarm jobs. The Southeast Asian experience has been largely of the latter variety, with rapid growth in rural nonfarm employment and income as a result of dynamic national economies (Rosegrant and Hazell 2000). Many Southeast

Asian countries seem to be following the Japanese experience, retaining large numbers of smallholder farms that are becoming part-time enterprises. Diversification is more likely to be associated with greater impoverishment when increasing land scarcity occurs in conjunction with slow agricultural growth, stagnant national and regional economies, and falling wages (Hazell and Reardon 1998). Such situations are not uncommon in many of the poorer countries in South Asia and Sub-Saharan Africa.

Although there are many explanations for current levels and trends in poverty around the world, agricultural growth is an important contributing factor. Its influence has been most studied for India. Prior to the Green Revolution in the late 1960s, the incidence of rural poverty in India fluctuated widely. Researchers obtained different results on the relationship between poverty and agricultural growth, depending on the period they chose for their analysis (Bardhan 1973; Ahluwalia 1978; Gaiha 1989; Ghose 1989; Griffin and Ghose 1979; Saith 1981). But after the Green Revolution began in the mid-1960s, the incidence of rural poverty began a definite downward trend (from about two-thirds to one-third of the rural population by the early 1990s). A greater consensus began to emerge in the literature on the poverty-reducing impact of agricul-

tural growth (Ghose 1989; Fan, Hazell, and Thorat 1999; Datt and Ravallion 1997). Rural poverty also declined dramatically in China after policy reforms launched rapid increases in agricultural growth and in the purchasing power of rural households (Fan, Zhang, and Zhang 2000). Rosegrant and Hazell (2000) report similar broad relationships across much of Asia during the Green Revolution era. Whereas 60 percent of Asians lived in poverty in 1975, this ratio had fallen to less than one in three by 1995, and the total number of poor declined from about 1.2 billion to about 0.8 billion despite a 1 billion increase in the total population.

Agricultural growth has not always improved income distribution, but by raising per capita

incomes across the board, it has significantly contributed to reducing the number of people living below the poverty line. In contrast, in Sub-Saharan Africa, where poverty is increasing and food insecurity is deteriorating, agricultural growth has been very disappointing, often struggling just to keep pace with population growth.

It would be dangerous to conclude too much from these patterns of association without more micro-based evidence on cause-and-effect relationships. Nor should it be concluded that agricultural growth necessarily reduces poverty. But the data do provide an optimistic backdrop that justifies more careful analysis of how technologically driven agricultural growth can benefit poor people.

3. How Agricultural Research Can Help the Poor

Agricultural research that leads to improved technologies can benefit the poor in a number of ways:

1. Research can help poor farmers directly through increased own-farm production, providing more food and nutrients for their own consumption and increasing the output of marketed products for greater farm income.
2. Small farmers and landless laborers can gain greater agricultural employment opportunities and higher wages within the adopting regions.
3. The poor can have opportunities to migrate to other agricultural regions.
4. Growth in the rural and urban nonfarm economy induced by more rapid agricultural growth can benefit a wide range of rural and urban poor people.
5. Research can lead to lower food prices for all consumers, whether from rural or urban areas.
6. Research can lead to greater physical and economic access to crops that are high in nutrients and crucial to the well-being of the poor—particularly poor women.
7. Research can empower the poor by increasing their access to decisionmaking processes, enhancing their capacity for collective action and reducing their vulnerability to economic shocks via asset accumulation.

These benefits do not necessarily materialize for the poor. Many conditioning factors determine who benefits from technological change. Nor do the benefits of research all necessarily work in the same direction. For example, while many of the poor may benefit from less costly food and greater opportunities for nonfarm income, production and employment benefits in the adopting regions may be disappointing or even perverse. Net outcomes, both for individual poor people and for entire poor populations, can be difficult to determine beforehand.

On-Farm Productivity Impacts

Poor farmers will obtain own-farm benefits from new technologies only if they adopt them. This means that the new technologies must be appropriate and profitable for farming conditions, and that poor farmers must have access to the knowledge and inputs necessary to adopt the technology. In principle, improved crop varieties are scale-neutral and can be adopted by farms of all sizes, but the same is not always true of other technologies or of complementary inputs like irrigation and machines, and access to fertilizers and credit. If institutions that provide these services and inputs are biased in favor of large farms, the poor may not be able to adopt new technologies.

To invest in new technologies whose returns occur over a number of years (for example, improved tree crops or better soil-management techniques) and to obtain credit to finance such long-term investments, poor farmers need secure ownership or tenancy rights. Insecure rights to

land may increase poor farmers' vulnerability to eviction should larger farmers and landlords want to expand their own cropped area as the result of more profitable technologies.

Under risky agroclimatic conditions, poor farmers may be reluctant to adopt profitable new technologies because they require input investments that could be lost in an unfavorable year. On the other hand, larger farmers are more likely to assume such risks because they have larger reserves and better access to credit and insurance.

Farmers who adopt new technologies often succeed in lowering their production costs per unit of output (though not usually per hectare), and therefore can better compete in the market. Moreover, if the technology is widely adopted and market prices fall as a result, the decline in unit cost may be essential for maintaining farm income. In this case, farmers who do not adopt the technology will be disadvantaged not only by stagnant production but also by declining prices and tighter profit margins. This profit squeeze can be detrimental to nonadopters within technology-adopting regions and to farmers who live in regions that are inappropriate for the new technology.

Even when poor farmers do benefit from significant productivity gains, these benefits are not always shared equitably among household members. In many societies, men and women have responsibility for growing different crops. Therefore, which crops benefit from technological change determines who controls the increased production within the household. Technological change for women's food crops may translate into better nutrition and well-being for women and children than technological change for men's cash crops (Haddad, Hoddinott, and Alderman 1997).

The initial experience with the Green Revolution in Asia stimulated a large body of empirical literature on how agricultural technological change affects poor farmers (see Kerr and Kolavalli 1999 for a recent review). Critics of the Green Revolution argued that because of

their better access to irrigation water, fertilizers, seeds, and credit, owners of large farms were the main adopters of the new technologies, and smallholders were either unaffected or harmed because the Green Revolution resulted in lower product prices, higher input prices, and owners' efforts to increase rents or force tenants off the land. Critics also argued that the Green Revolution encouraged unnecessary mechanization, with a resulting reduction in rural wages and employment. The net result, critics said, was an increase in inequality of income and asset distribution and a worsening of absolute poverty (see Griffin 1974; Frankel 1976; Farmer 1977; ILO 1977; Pearse 1980).

Although a number of village and household studies conducted soon after the release of Green Revolution technologies lent some support to early critics, more recent evidence shows mixed outcomes (Blyn 1983; Pinstrip-Andersen and Hazell 1985; Lipton and Longhurst 1989; Hazell and Ramasamy 1991; David and Otsuka 1994). Although small farmers did lag behind large farmers in adopting Green Revolution technologies, many of them eventually did so. Many of these small-farm adopters benefited from increased production, greater employment opportunities, and higher wages in the agricultural and nonfarm sectors. Moreover, most small farmers were able to hold onto their land and captured significant total production increases from their holdings (Westley 1986; Hazell and Ramasamy 1991; Rosegrant and Hazell 2000). In some cases, small farmers and landless laborers actually ended up gaining proportionally more income than larger farmers, with a net improvement in the distribution of village income (Hazell and Ramasamy, 1991).

This is not to say that the Green Revolution was equitable everywhere (Freebairn 1995). But the conditions under which it and similar yield-enhancing technologies are likely to have equitable on-farm benefits are now reasonably well understood. These include: (1) a scale-neutral technology package that can be profitably adopted

on farms of all sizes; (2) an equitable distribution of land with secure ownership or tenancy rights; (3) efficient input, credit, and product markets so that farms of all sizes have access to needed modern farm inputs and information and are able to receive similar prices for their products; and (4) policies that do not discriminate against small farms and landless laborers (for instance, no subsidies on mechanization and no scale-biases in agricultural research and extension). These conditions are not easy to meet. Typically, government must make a concerted effort to ensure that small farmers have fair access to land, knowledge, and modern inputs.

Agricultural Employment and Wages

Many yield-enhancing technologies increase total on-farm employment, particularly if they expand the gross cropped area, for example, by growing more crops per year with irrigation and short-season crop varieties. This can lead to less seasonal fluctuation in employment earnings. But whether all this translates into higher wage earnings for the poor depends in large part on the elasticity of the labor supply. If labor is abundant in the adopting region, then additional employment will have little effect on wages, workers will gain, and farmers will have limited incentive to invest in labor-displacing machines. But if the labor supply is inelastic, wages will rise sharply and labor-displacing machines may become attractive. Initial mechanization may be targeted on labor-intensive tasks like plowing and threshing, but once farmers invest in tractors the incremental costs of mechanizing other tasks may become quite low, causing more widespread displacement of labor. Mechanization may also occur prematurely if government policies such as cheap credit for large farms make mechanization less costly.

Population growth increases the supply elasticity of labor and therefore acts to dampen wage

increases. This may lead to greater agricultural employment, but lower living standards for workers. The decline in living standards can be particularly sharp if rapid population growth coincides with adoption of agricultural technologies with low employment elasticities.

Impact on Inter-regional Migration

Technological change in agriculture is usually site-specific and does not benefit all regions equally. The Green Revolution was initially concentrated in irrigated regions and only later spread to more favorable rainfed areas. Technological change, therefore, can contribute to widening disparities between regions. Worse, if the technology leads to lower production costs per unit of output in the adopting regions, producer prices may fall, leaving non-adopting regions with lower prices as well as stagnant yields, so that their incomes could actually decline. But inter-regional migration acts to buffer these gaps and provides an efficient way of spreading the benefits to poorer regions with more limited agricultural growth potential.

In India, the Green Revolution led to the seasonal migration of more than a million agricultural workers each year from the eastern states to Punjab and Haryana (Westley 1986). Moreover, in a study of the impact of the Green Revolution in a sample of Asian villages, David and Otsuka (1994) found that seasonal migration played an important role in spreading the benefits between technology-adopting and -nonadopting regions. But even though migration can buffer widening income differentials between regions, it is rarely sufficient to avoid it. In India, poverty in many low-potential rainfall areas has changed little even while irrigated and high-potential rainfall areas have progressed (Fan and Hazell 2000). Regional inequalities have also worsened in China in recent years (Knight and Song 1992; Zhang and Fan 2001).

Impact on the Nonfarm Economy

Agricultural growth generates important rounds of income and employment growth within the nonfarm economy. These are driven by (1) increased demands for additional farm inputs, investment goods, and marketing services (demands that often increase per hectare with technological change); (2) increased rural household demands for consumer goods and services as farm and wage incomes rise; and (3) generation of farm savings, foreign exchange earnings, and lower prices for foods and other primary commodities.

This paper distinguishes between the rural nonfarm economy, including its market towns, and the broader urban-based national economy. The rural nonfarm economy has more transparent links to agriculture and is especially important to the rural poor. However, there are also powerful links between agricultural and national economic growth that benefit society at large, including the rural and urban poor.

The Rural Nonfarm Economy

The rural nonfarm economy is of special importance to the rural poor and to the urban poor living in rural towns. Landless and near-landless households everywhere depend on nonfarm earnings. Those with less than half a hectare earn between 30 and 90 percent of their income from nonfarm sources (Haggblade, Hazell, and Brown 1989; Rosegrant and Hazell 2000). Nonfarm shares are strongly and negatively related to farm size. Low-investment manufacturing and services—including weaving, pottery, gathering, food preparation and processing, domestic and personal services, and unskilled nonfarm wage labor—account for a greater share of income for the rural poor than for the wealthy (Hazell and Haggblade 1993). The reverse is true of transport, commerce, and such manufacturing activities as milling and metal fabrication, which require sizable investments.

Nonfarm income is also important to the poor as a means to help stabilize household income in drought years (Reardon et al. 1998). In a study of several villages in the semi-arid tropics of India, for example, Walker and Ryan (1990) found that nonagricultural self-employment and labor market earnings became increasingly important sources of income during the 1980s, increasing mean income and dampening household income variability.

Numerous studies have shown that agricultural growth generates important income and employment multipliers within the surrounding nonfarm economy. The multipliers are particularly large in Asia, with \$0.5 to \$1.0 of additional income created in the local nonfarm economy for each dollar of additional income created in agriculture (Bell, Hazell, and Slade 1982; Hazell and Ramasamy 1991; Haggblade and Hazell 1989). The multipliers are about half as large in Africa and Latin America (Haggblade and Hazell 1989).

The multipliers are predominantly driven by increased rural household demands for consumer goods and services as farm incomes rise. Small, informal, and labor-intensive rural nonfarm firms supply many of these goods and services. This leads to high nonfarm employment elasticities within rural regions. Often, each 1 percent increase in agricultural output is associated with a 1 percent increase in rural nonfarm employment (Gibb 1974; Hazell and Haggblade 1991).

The strength of the regional growth linkages is higher in labor-abundant regions and increases with regional development and per capita incomes. Irrigated regions dominated by medium-sized farms and modern input-intensive farming systems generate the largest multipliers. The multipliers are smaller in rainfed farming systems and in regions dominated by very small farms or large estates (Haggblade and Hazell 1989). In India, for example, the multipliers are largest in Green Revolution states like Punjab and Haryana and smallest in less developed states like Bihar and Madhya Pradesh (Hazell and Haggblade 1991). As regions develop and labor markets tighten,

employment impacts become less important. The lower multipliers in Africa are attributable to low per capita incomes (which are mostly spent on food), poor infrastructure, and farming technologies that require few purchased inputs (Haggblade and Hazell 1989). In Latin America, higher per capita rural incomes ought to lead to larger multipliers, but often fail to do so because the distribution of income is highly inequitable and the richer households have much stronger consumption linkages to cities than the rural nonfarm economy.

Rural income multipliers and employment elasticities of the sizes observed in Asia mean that technological change in agriculture has the potential to generate significant new nonfarm income-earning opportunities for the poor. These may arise in the form of greater nonfarm employment, higher wages, and opportunities for the poor to start or expand nonfarm businesses of their own. Increasing competition for labor between agriculture and the local nonfarm economy can also contribute to higher agricultural wages for the poor.

The benefits of growth in the rural nonfarm economy are concentrated in towns more than villages, affecting an important segment of the nonfarm poor residing in towns. Distribution of benefits between rural farm areas and towns depends on the state of infrastructure connecting the two, on population density, on government policies, and on average per capita income levels (Haggblade, Hazell, and Brown 1989).

The National Economy

Agricultural growth has broad general equilibrium (GE) impacts on the national economy that vary according to stage of economic development. In poorer countries, agriculture accounts for the lion's share of national income, employment, and export earnings. Under these conditions, even a modest growth rate for agriculture can have significant leverage on the national economy. Rapid agricultural growth contributes to the economic transformation of a country in a number of important ways. It:

- supplies basic foods, raw materials for agroindustry, and exports, and frees up foreign exchange for the importation of strategic industrial and capital goods.
- releases labor and capital (in the form of rural savings and taxes) to the nonfarm sector. Generates purchasing power among the rural population for nonfood consumer goods and services, supporting growth in services and trade.
- provides a nascent market for an emerging manufacturing sector.
- reduces poverty by increasing labor productivity and employment and by lowering food prices for all.

As the transformation of an economy advances, agriculture's share in national income falls and its importance for national economic growth diminishes. The nonagricultural sector becomes the primary engine of growth and is no longer as dependent on resource flows from agriculture or on agriculture's demand linkages. However, agriculture's share of total employment falls more slowly than its share of national income, with the inevitable result that agricultural labor productivity, and hence per capita farm incomes, lag behind the nonagricultural sector. The problem is then to absorb workers out of agriculture at a sufficiently rapid rate to stop their average productivity (and hence their incomes) from lagging too far behind the levels achieved in the nonagricultural sector. Few countries have been able to manage this transition successfully. Either rural poverty has persisted until late in the development process or governments have engaged in expensive farm-income support policies.

Empirical studies confirm the importance of these GE effects in developing countries. In India, the fact that the nonfarm share of total national employment did not change for over a century until the full force of the Green Revolution was underway in the 1970s provides strong circum-

stantial evidence of the importance of agricultural growth as a motor for India's nonfarm economy. Rangarajan (1982) confirmed this, estimating that a 1 percent increase in the agricultural growth rate stimulated a 0.5 percent rise in the growth rate of industrial output and a 0.7 percent rise in the growth rate of national income.

Computable general equilibrium (CGE) modeling studies show that these GE effects are stronger in economies that have more liberalized trade and that invest in adequate levels of rural infrastructure and service provision (Robinson, Roe, and Yelden 1998). Modeling results also confirm that agriculture-led growth strategies are more beneficial for overall economic growth than industry-led strategies, particularly in agrarian economies (Adelman 1984; De Franco and Godoy 1993).

Impact on Food Prices and Diet Quality

Technological change contributes to increases in the aggregate output of affected commodities and often lower unit costs. This has proved to be one of the most important ways through which poor people have benefited from technological change in agriculture (Scobie and Posado 1978; Rosegrant and Hazell 2000; Fan, Hazell, and Thorat 1999).

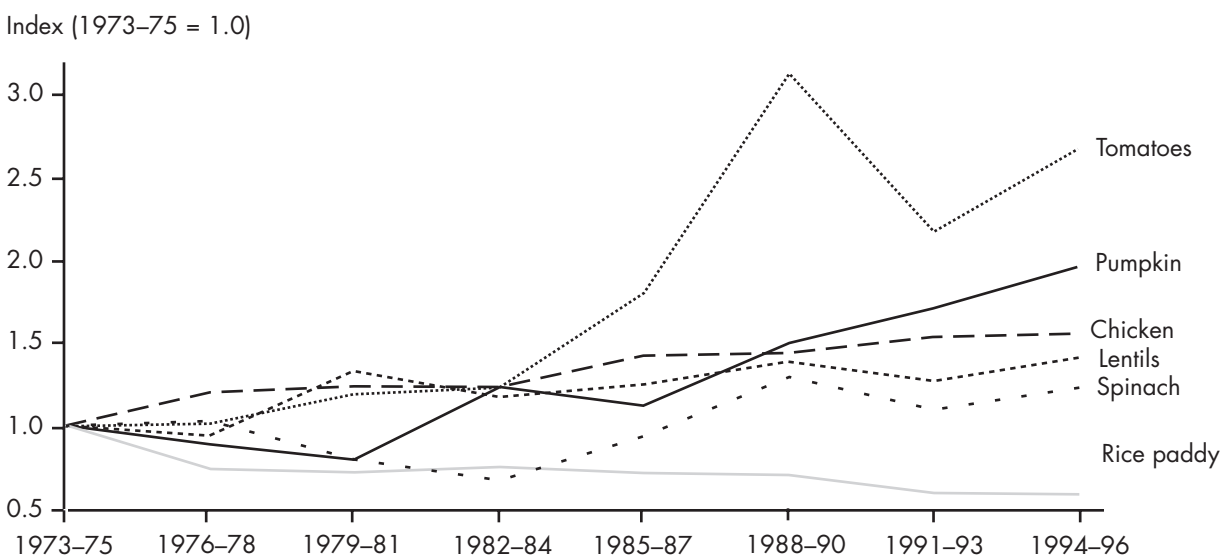
If the demand for these products is downward sloping (that is, export opportunities are constrained by trade policy or by high transport costs), the output price will fall. The more elastic the supply relative to demand, the greater the price decline will be (Alston, Norton, and Pardey 1995). Lower food prices benefit rural and urban poor alike. Because food accounts for a large share of their total expenditures, the poor gain proportionally more than the nonpoor from a decline in food prices (Pinstrup-Andersen and Hazell 1985). These price effects may be muted in open economies with low transport costs. More countries now fall into this category than before

because of recent rounds of market liberalization policies. But many poor countries still face high transport costs because of poor infrastructure, remoteness from world markets, or inefficient marketing institutions. Hence, domestic prices are still responsive to local supply even after market liberalization. In many landlocked African countries, for example, domestic prices still fall sharply when domestic food production increases suddenly. Some traditional food crops are not traded in world markets, and therefore yam, millet, taro, and teff prices continue to be endogenously determined within the countries that grow them.

Food-price benefits may be enhanced if technological change leads to lower production costs per unit of output. Farmers can then maintain or increase profits even selling at lower prices. But whether consumers benefit from these lower costs depends on the food marketing and distribution system being sufficiently competitive so that cost savings at the farm gate are passed up through the marketing chain. In some cases, the cost savings are simply captured as additional profits in the marketing chain.

Technological changes that smooth seasonal food supplies, such as irrigation and short-season rice varieties, can help smooth seasonal price variation. This can be of considerable benefit to the poor. The rural poor may become more food-secure from increased local production by reducing the need to purchase food from outside the region. Locally grown produce is cheaper because there is no need to cover high transportation costs.

Food-price declines amount to an increase in real income for net food-purchasing households. Real-income increases can be used to increase consumption of important staples and to purchase more diverse, nutritionally rich diets. What is the best way to improve the nutrient content of the poor people's diets through agricultural research? By concentrating on increasing incomes through productivity-enhancing investments in staple foods or by concentrating on decreasing the relative prices of micronutrient-rich foods?

Figure 3—Food price trends in Bangladesh, 1973–96

Source: Bouis 2000.

Figure 3 shows a downward trend in the price of rice in Bangladesh. However, it also shows upward trends in the real prices of other foods that are richer in micronutrients. This may reflect underinvestment in technologies for the production of nutrient-rich foods such as fruits, vegetables, and nonruminant livestock. Areas that are more remote tend to have less access to perishable foods via the marketplace, so investment in these crops may well deliver the highest return in terms of micronutrients delivered per dollar of research resources spent. In areas with good market access, the question is more complicated, since access to micronutrient-rich foods is dependent on food-price elasticities, the extent to which women control of household income, and the quality of information and education programs related to diet.

Enhancing the Nutrients in Staple Food Crops

Agricultural research that enhances the nutrient quality of foods poor people eat can directly improve their diets. Breeding maize for higher quality proteins is an early example. Unfortunately,

the rapidly changing consensus in the nutrition community as to the limiting factors in the diet (from protein to calories and micronutrients) made the quality-protein maize (QPM) experience somewhat demoralizing for the plant-breeding community (Tripp 1990).

Despite this recent history, a new generation of plant-breeding efforts is underway (see Graham and Welch 1996 for a good summary). The focus this time is not on protein, but on micronutrients. There are three broad goals: (1) increase the micronutrient concentration in the crop, (2) decrease the concentration of absorption inhibitors such as phytic acid, and (3) increase the concentration of promoter compounds (for iron and zinc in particular) such as sulphur-containing amino acids (Ruel and Bouis 1998). The two broad technologies are traditional breeding (looking for naturally occurring genetic variation in micronutrient content) and biotechnology (genetic modification of foods and the creation of new foods).

The breeding approaches face many challenges. Can high nutrient-density cultivars be found with (1) little or no yield trade-off so that farmers will be interested in adopting them, (2) lit-

the impact on consumer acceptance (storage, cooking, appearance, and taste), and (3) no negative impact on bioavailability (for the strategies that increase micronutrient density)? These challenges are similar to those faced by other food-based interventions, but with the added baggage of the QPM experience.

Compared to the traditional breeding approach, the biotechnology work is at a much earlier stage. But it is yielding promising results. The Swiss Federal Institute of Technology's Institute for Plant Sciences has demonstrated some success in introducing genes that increase iron and vitamin A concentrations in rice (the so-called "golden" rice). The Swiss team plans to collaborate with the International Rice Research Institute (IRRI) to test the health and environmental consequences of the technology and to evaluate the acceptability of the rice to farmers in terms of yield impacts.

Impact on the Vulnerability, Assets, and Empowerment of the Poor

Poverty is more than a lack of sufficient income or food to meet basic material needs. It is also a state of social deprivation, involving vulnerability and lack of participation in decisionmaking and in civil, social, and cultural life. It places a wide array of limitations on the capacity of the poor to substantially improve their lives. The lack of capacity or power is itself a fundamental characteristic of being poor (Carney 1998).

The assets that individuals, households, and communities control are critical for their capacity to cope with vulnerability and to establish secure livelihoods. In many developing countries, the poor are highly dependent on natural resources within their local environments. Poverty therefore can be exacerbated by not having access to those resources. The cycle is self-perpetuating when poor people have no access to technologies and inputs that enable better use of resources, or when the poor do not participate in the design and evaluation of those technologies. In addition, lack of access to financial and human capital, social networks, and political power compound conditions

of poverty and vulnerability. Access to assets is important, but so is the ability to use them in combination to create secure livelihoods. Assets can be seen as a base of power, enabling people "to act and to reproduce, challenge, or change the rules that govern the control, use, and transformation of resources" (Bebbington 1999).

Recognizing that the lack of capacity is a component of poverty, development practitioners are focusing on empowerment. Kerr and Kolavalli (1999) define empowerment as "a development strategy that seeks to bring about change through modifications in the power structure, changing the social order in which the poor live." They distinguish between two types of empowerment: motivational, which involves enhancing peoples' abilities thereby contributing to greater confidence and self-reliance, and relational, which implies changing power structures and gaining access to political decisionmaking. The objectives of empowerment are increased self-reliance and self-determination—essential tools for breaking out of the poverty trap as well as pursuing a prosperous, fulfilling life.

Empowerment tools can offer users of local resources better access to and control over the local environment as well as associated production and conservation technologies. Some of the most fundamental empowerment tools include property rights (which strengthen the asset base), local collective action and organizations (such as cooperatives and microcredit groups), and political organization and advocacy. But agricultural technology can also contribute to empowerment, particularly if the poor participate in technology development. Who decides research priorities and technology development approaches are two important aspects of how research systems operate. In most countries, resource-poor farmers in unfavorable regions are passive recipients of technologies; they have no control over the priorities of the research systems that serve them. The research process ignores farmers' knowledge and experience even though they may offer insights that could help develop effective technologies for

unfavorable areas. Such systems may perpetuate a sense of helplessness among resource-poor farmers who wait in vain for effective technological solutions to come from outside.

Participatory research and dissemination strategies offer an alternate approach based on empowerment, building farmers' own capability to innovate and giving them greater influence over decisions in agricultural research. Participatory research involving women farmers can also contribute to their empowerment. Participatory research and dissemination approaches where farmers communicate results within and between communities can enhance the asset base of people and communities by building social capital and organizational capacity.

Net Impacts on the Poor

Poor people have complex livelihood strategies. The rural poor, for example, are often part farmers, part laborers, and part nonfarmers—and always consumers. As such, they may gain or lose in different dimensions at the same time, so that the net impact of technological change on poor households can remain ambiguous. A poor farmer might be able to gain from increased on-farm production as a technology adopter, but may lose or gain from increased agricultural wages or reduced food prices depending on whether he or she is a net buyer or seller of labor or food. A small, nonfarm, business entrepreneur might gain from cheaper food, but business profits might fall or rise depending on whether or not hired labor costs rise faster than sales. There is also a temporal dimension to these outcomes, with some costs and benefits being realized before others have had time to work through (for example, GE impacts take longer to materialize than on-farm benefits). Understanding household livelihood

strategies and the dynamics of change is therefore fundamental for assessing the impact of technological change at the household level.

Assessing how technological change affects the poor in aggregate is even more complex and uncertain. Not only is there complexity in assessing the net impacts on different types of poor households, but the various direct and indirect impacts also affect different types of poor households in different ways. Some poor households may be net gainers while others are net losers. It is possible, for example, that the indirect growth and food-price benefits are strong and generally favorable for the urban poor, but that they are weaker in rural areas and perhaps are even offset by adverse direct impacts because of inequitable land distribution or poor service support for small farmers. Whether there is a net gain or loss to the poor in aggregate will then depend on how many of them are rural and the relative size of the gains and losses that different groups experience.

It is also necessary to distinguish between long- and short-term impacts on the poor. Direct benefits within technology-adopting regions are appealing because they can almost immediately and transparently affect the rural poor. Indirect growth and food-price benefits take longer to materialize, and their links to agricultural technology are less apparent. However, the indirect benefits can be much more important in the long term for reducing both urban and rural poverty. In Asia, for example, although the Green Revolution had mixed direct impacts on the rural poor, its contributions to productivity enhancement were a major factor in reducing food prices and in launching the rapid economic growth of the region. This growth led to significant increases in per capita incomes (especially in Southeast Asia) and a decline in the number of people living in poverty (Asian Development Bank 2000; Rosegrant and Hazell 2000).

4. Targeting Agricultural Research to Benefit the Poor

Chapter 3 highlights the important role that a number of national and local characteristics play in conditioning the ways in which agricultural technologies affect the poor and the difficulty of generalizing about when technological change will benefit the poor. To target pro-poor agricultural research more effectively, the types of research undertaken need to be tailored to specific country and region conditions. A key question is whether one can go beyond pure site specificity and identify sufficient commonalities across sites to construct a typology that can serve as a filtering device for selecting appropriate types of agricultural research for different socioeconomic contexts.

A Typology

This chapter develops a typology of agricultural regions based on agroclimatic and socioeconomic factors that condition the size and distribution of the benefits that might be obtained from technological change. Although such a typology would seem essential for helping to target pro-poor agricultural research, its construction does not seem to have been attempted before. This attempt is largely exploratory (even speculative) but it is hoped that it lays a useful foundation for future work. To construct the typology, the more important conditioning factors of the size of the direct and indirect benefits identified in the previous chapter are used as classification criteria, with differentiation between national and local or region-specific factors.

National Characteristics

1. *Market liberalization policies and national rural infrastructure development.* Countries that pursue liberal trade policies and liberalize their domestic markets typically grow faster than other countries and this contributes to greater long-term reductions in poverty (World Bank 2000). These growth effects can be even stronger in agrarian-based economies (for example, much of Africa and South Asia) when trade liberalization is complemented by increased investment in rural infrastructure (Robinson, Roe, and Yelden 1998). National investments in agricultural research and rural infrastructure also contribute to agricultural and rural nonfarm economic growth and to rural poverty reduction in their own right, even when markets are not widely liberalized (Fan, Hazell, and Thorat 1999; Fan, Zhang, and Zhang 2000). Agricultural research can be expected to contribute more to growth and therefore to long-term poverty reduction in countries with liberalized markets and good levels of rural infrastructure. By connecting farmers to larger markets, both domestic and international, and enhancing economic growth, farmers may benefit from greater opportunities to diversify into higher-value products. These are typically employment-intensive and can benefit smallholder farms and landless workers. Moreover, the prices farmers receive for staples are less likely to fall as production increases, enabling food-surplus farmers to capture larger shares of the productivity increases arising from technological change. The downside to this is that consumers and food-deficit farmers are less likely to benefit from price reductions for staple foods as

production increases, though they may benefit from more plentiful supplies of higher value and more nutritious foods, such as vegetables, fruits, and livestock products. Farmers living in remote regions also face potential hardships if they are unable to compete in more liberalized markets because of higher transport and marketing costs. Smallholder farms everywhere may also be unable to compete in markets for higher-value products if they are unable to organize and market their smaller volumes of output competitively with large farms.

2. *National per capita income level.* As countries grow and national per capita incomes rise, agriculture's share in national income diminishes. This has a number of important implications for growth-poverty relationships. First, because households allocate increasing shares of their income to nonfoods as they get richer, rising per capita incomes have a powerful impact on both the level and composition of demand for foods and nonfoods. Rural nonfarm income multipliers tend to be larger with higher per capita incomes, a situation that benefits the rural poor, but broader general equilibrium effects on the national economy get smaller as the agricultural sector becomes relatively less important. Second, the structure of poverty also changes with increases in average per capita incomes, with clearer demarcation of hard-core poor poverty groups that do not easily benefit from agricultural and national economic growth. These poverty groups tend to concentrate in urban areas and less-favored or marginal regions. Third, since agriculture's employment share typically diminishes at a slower rate than its income share as per capita incomes rise, labor productivity lags behind that of other sectors. This can lead to worsening inequality between farm and nonfarm incomes, though not necessarily to worsening poverty. Technologies and policies to increase average labor productivity therefore become more important as countries develop.

3. *The share of poor who are urban.* The direct benefits of agricultural technology for the

poor will be smaller if the poor are predominantly urban-based. In these cases, indirect effects such as food price changes and growth of the nonfarm economy will be much more important, especially in countries that are not well integrated with global food markets. It is then appropriate to give greater attention to pure productivity gains in domestic agriculture (with an eye to the relative prices of foods that are key for the eradication of diet-quality problems of the urban poor) rather than worrying about their social distribution within the rural sector. The opposite holds when the poor are predominantly engaged in agriculture.

4. *Population growth.* Population growth adds to the rural labor supply in agrarian countries and, other things being equal, acts to reduce wages. Rapid population growth can lead to stagnant living standards and can mask gains from technological change. Population growth typically declines as per capita incomes rise, but where this is not true, then agricultural growth should continue to be labor intensive until late in the development process.

Regional or Local Characteristics

1. *Agroclimatic conditions.* The agroclimatic conditions of a region determine whether it has high or low potential for agriculture. The use of modern inputs and the potential to achieve higher levels of output per hectare and per worker are typically greater in high potential areas (HPAs), creating greater growth opportunities for reducing local poverty. But even many low-potential areas (LPAs) can achieve high levels of output per hectare if they have good infrastructure and access to markets (through livestock and tree crop production, for example, rather than staple foods). Unfortunately, many LPAs have also been neglected through past patterns of public investment and have weak infrastructure and market access, which greatly restricts their ability to improve agricultural productivity and reduce poverty. Because the development of the local nonfarm economy also hinges crucially on agricultural growth to generate markets for most of its products, there are

typically fewer opportunities for farmers and landless workers to diversify into productive nonfarm activities in LPAs. In short, the rural nonfarm economy tends to be much weaker in LPAs and stronger in HPAs, reinforcing the initial inequities in agroclimatic conditions (Hazell and Reardon, 1998).

2. *Labor market situation.* Agricultural wage earnings for the poor tend to be greater when agriculture has a high employment elasticity. In South Asia, employment elasticities of around 0.7–0.8 were observed during the peak of the Green Revolution (that is, each 1 percent increase in agricultural output led to a 0.7–0.8 percent increase in agricultural employment), but employment elasticities are probably about half that level today. The rural nonfarm economy also has a high employment elasticity (often around 1.0), so that the combination of an employment-elastic agriculture and a vibrant rural nonfarm economy can lead to strong growth in demand for rural labor, which can be very beneficial for the poor. On the other hand, an abundant or elastic supply of labor (such as occurs with rapid population growth but slow agricultural growth) keeps wages down, thereby diluting the benefits of growth in employment opportunities for the poor. Promotion of labor-intensive crop and livestock technologies are particularly important in labor-abundant regions, as is the need to avoid policies and investments that lead to premature mechanization of farming.

3. *Land distribution and the incidence of landlessness.* An unequal distribution of land reduces the percentage of the rural poor who can gain from own-farm productivity increases and typically contributes to excessive mechanization and low employment elasticities in agriculture. It also leads to weaker demand for local nonfood goods and services, and hence to smaller rural income and employment multipliers. Technological change rarely contributes to rural poverty reduction in technology-adopting regions when the distribution of land is badly skewed, as amply demonstrated by some experiences with the Green Revolution.

4. *Infrastructure and the provision of key agricultural services.* These are essential for ensuring that poor farmers can adopt new technologies and take advantage of new income-earning opportunities such as diversification into higher value products. They also affect the size of the nonfarm income multipliers within an adopting region. Regions with poor infrastructure and service support are not only likely to be poorer, but poor farmers living within those regions are less likely to be able to adopt improved technologies.

5. *Local institutions and empowerment.* Cultural and institutional factors that work against the poor are not easily overcome by economic changes alone. These factors can include racial, tribal, and religious discrimination, gender biases, exclusive property rights arrangements, local power structures that favor the rich, and poor delivery of public services to needy groups and less developed regions. In regions where such biases are strong, technological change in agriculture may sometimes work against the interests of the poor. Improved governance arrangements and greater empowerment of the poor may then need to be a prerequisite for successful pro-poor agricultural growth.

The list of criteria is too long for a practical typology, and it is necessary to cluster some of these criteria to obtain a more manageable number. Fortunately, some important national characteristics are strongly correlated. The World Bank classifies countries by per capita income level, and two groups of countries are important for this study: low-income countries (LICs) that had 1999 per capita incomes below \$755 and middle-income countries (MICs) that had 1999 per capita incomes of between \$756 and \$9,265. As Table 4 shows, this classification reveals that LICs not only have lower per capita incomes than MICs (\$410 versus \$2,000) but they also have smaller urban population shares, higher population growth rates, and larger agricultural sector shares in national output. The income classification of a country therefore is used as a proxy for these three variables. But Figure 4 provides a cautionary

Table 4—Comparison of low- and middle-income countries

Indicator	Low-income countries	Middle-income countries
GNP per capita (1999 US\$)	410	2,000
Urban population (% total in 1999)	31	50
Annual population growth rate (%), 1990–99	2.0	1.2
Agriculture's share in GDP (% in 1999)	27	10
Population density (people/square kilometer in 1999)	73	40
Arable land per capita (hectares in 1995–97)	0.19	0.23

Source: World Bank 2000.

reminder that there is still considerable variation in these relationships within the two country groups and that one must be careful in practice not to assume too much for a particular country situation.

It is also reasonable to merge concern for the level of national investment in rural areas and local or regional development of infrastructure and agricultural services and to define this variable at the regional level. Finally, a strong and positive association between an inequitable distribution of land and a high incidence of landlessness with institutional and cultural biases against the poor is hypothesized. Taken together, these factors can be considered an index of empowerment of the poor at the regional level, defined in terms of their access to land and other resources, and to public services.

With these changes, a regional typology can be defined based on two country characteristics and four local characteristics:

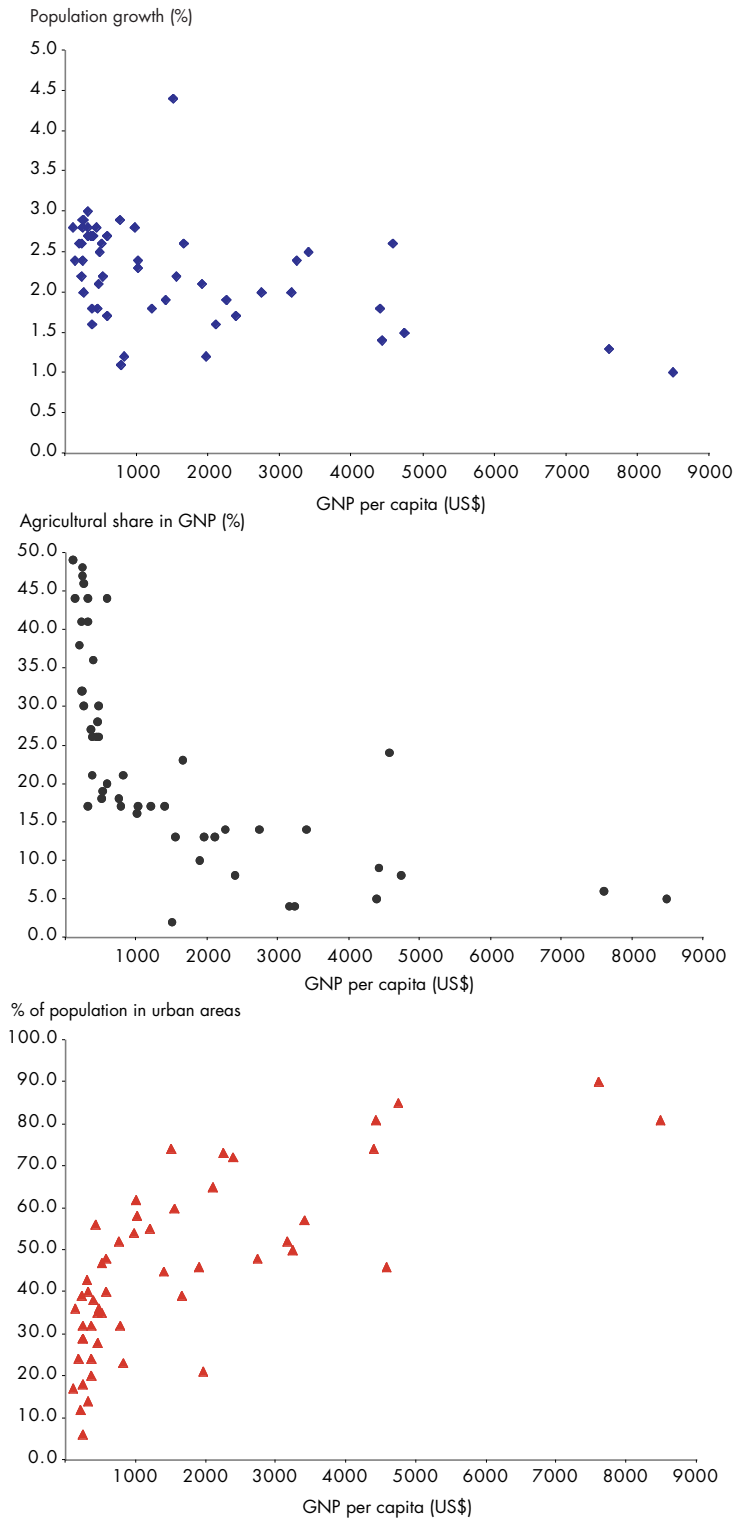
- region located in a low- versus middle-income country;
- region located in a country with liberalized versus unliberalized market and trade policies;
- region has high versus low agroclimatic potential for agricultural growth;
- region has good vs. poor rural infrastructure, service provision, and market access;

- region has low wages and abundant labor supply versus high wages and scarce labor supply; and
- region has favorable versus unfavorable empowerment of the poor.

Implications for Agricultural Research Priorities

Table 5 shows how the typology can be used to set priorities for agricultural research that will be most appropriate for reducing poverty in different types of regions and country situations. Two types of priorities are captured in this summary: (1) inter-regional allocation of research resources to achieve the largest reduction in poverty at the national level and (2) the kinds of research that are most appropriate within individual types of regions. Reading across a row (corresponding to a type of country) in Table 5, the shaded cells depict the types of regions that should receive highest research priority within such countries. The digital codes in the cells depict priority research activities within each type of region. Of course, not all countries have all the types of regions shown in the table, in which case there are fewer interregional choices to be made. The unshaded cells in the table depict regions where research is more likely to lead to smaller net reductions in national poverty than if the same resources were

Figure 4—Relationships between GNP per capita and population growth, agriculture’s share in GNP, and urbanization in low- and middle-income countries



Source: World Bank 2000.

allocated to shaded regions. But research in these regions may still benefit important poverty groups.

Although empowerment of the poor was identified as a classification criterion in constructing the typology, the cells in Table 5 are not disaggregated by this criterion. This is because the types of research considered in the table are defined at a high level of generality, and the appropriate choice at this level is less one of selecting the type of research or technology needed to empower poor people than of choosing the way in which agricultural research and extension is conducted. Agricultural research can contribute to the empowerment of the poor if conducted in participatory ways, but on its own it has limited capacity beyond labor market impacts to directly overcome the problems of seriously disempowered people who are denied access to land and other key resources and public services.

In these cases, new technologies may bring significant changes for the poor only if complementary social and political changes are undertaken. Appropriate actions might need to include land redistribution programs, rental market reforms, microfinance to increase the assets of the poor, and improved delivery of public services to the poor. In some cases, social action may be required to organize poor people for greater political voice in local decisions that affect them, or for better access to and management of common property like communal grazing and woodlot areas. This often requires direct interventions by grassroots organizations such as NGOs or the reform of local government. Agricultural research systems have little capacity or mandate to undertake this kind of work, but they may need to develop new kinds of partnerships with other types of development agencies if their technologies are to benefit the disempowered poor.

In LICs, the importance of staple foods in rural livelihoods and the national diet requires that high national priority be given to agricultural research that increases staple food production in high-potential areas. This will create larger marketed surpluses and benefit large numbers of poor peo-

ple. But where national staple food surpluses have already been achieved, or where infrastructure and markets are weak, production increases will need to be spread more broadly across regions (including some LPAs) to achieve widespread food security. Because national demands for higher-value crop and livestock products are limited at low per capita income levels, significant research on these products may be relevant only where there are major export opportunities. These are more likely to occur in countries that have liberal market and trade policies. However, attempts to improve the nutrient quality of food staples may have high payoffs for improving the nutritional well-being of the poor, especially in regions with inadequate infrastructure and market access.

Research priorities for different types of regions within LICs need to be adjusted to their key characteristics if they are to be most helpful to the local poor. In labor surplus regions, emphasis should be placed on the development of staple food technologies that are labor-intensive and are attractive to smallholder farms. In labor-scarce regions, technologies should enhance labor productivity, and this may require focus on some forms of mechanization. Technologies that require intensive use of fertilizers, purchased seeds, and pesticides will be more relevant for regions that have high agricultural potential and good infrastructure and market access, while improved natural resource management and low external-input farming technologies will be more relevant for LPAs and/or regions with weak infrastructure and inadequate market access. Poor farmers are least likely to be able to afford modern inputs in LPAs, a pattern that is reinforced when they are disempowered in their access to land, other resources, and public services.

In MICs, high priority should be given to increasing agricultural productivity through diversification into higher-value crops and livestock in most kinds of regions with reasonable infrastructure and market access. Staple foods are still important, but except in MICs that have not liberalized their trade and markets, staple food

Table 5—Priorities for agricultural research to reduce national poverty by type of adopting region

Country setting	Regional characteristics											
	Good infrastructure				Scarce labor				Poor infrastructure			
	Surplus labor Low potential	High potential	Low potential	High potential	Surplus labor Low potential	High potential	Scarce labor Low potential	High potential	Surplus labor Low potential	High potential	Scarce labor Low potential	High potential
Middle-income country												
Markets liberalized	1, 2, 3, 5	2, 3, 5, 8	1, 4, 6	4, 6, 8	1, 3, 5, 7	3, 5, 8	1, 4, 6, 7	4, 6, 8	1, 3, 5, 7	3, 5, 8	1, 4, 6, 7	4, 6, 8
Markets not liberalized	1, 2, 3, 5	1, 2, 3, 5, 8	1, 4, 6	1, 4, 6, 8	1, 3, 5, 7, 9	1, 3, 5, 8	1, 4, 6, 7, 9	1, 4, 6, 8	1, 3, 5, 7, 9	1, 3, 5, 8	1, 4, 6, 7, 9	1, 4, 6, 8
Low-income country												
Markets liberalized	3, 5	1, 2, 3, 5, 8	2, 4, 5, 8	1, 2, 4, 5, 6, 8	1, 3, 5, 7, 9	1, 3, 5, 7, 9	1, 4, 5, 7, 9	1, 4, 5, 7, 9	1, 3, 5, 7, 9	1, 3, 5, 7, 9	1, 4, 5, 7, 9	1, 4, 5, 7, 9
Markets not liberalized	1, 3, 5, 9	1, 3, 5, 8, 9	1, 4, 5, 8, 9	1, 4, 5, 8, 9	1, 3, 5, 7, 9	1, 3, 5, 7, 9	1, 4, 5, 7, 9	1, 4, 5, 7, 9	1, 3, 5, 7, 9	1, 3, 5, 7, 9	1, 4, 5, 7, 9	1, 4, 5, 7, 9

Priorities for agricultural research:

1. Staple food production
2. High-value crops, trees and livestock
3. Employment intensive growth
4. Increased labor productivity
5. Smallholder farms
6. Medium and large farms
7. Low external-input farming
8. High external-input farming
9. Nutritional content of food staples

research should receive greatest priority in LPAs that have poor infrastructure and their own food security problems, and in HPAs that have continuing comparative advantage in growing these crops. Smallholders continue to deserve priority in all labor-surplus areas, but research priorities in labor-scarce regions should be consistent with the need to increase holding sizes, particularly in regions that have good infrastructure and vibrant local nonfarm economies and that are well connected to urban areas. Labor-intensive technologies remain important in labor-surplus regions, but diversification into higher-value crops and livestock can also add significantly to local employment. High external-input farming is more widely applicable in MICs, except perhaps in

LPAs that have poor infrastructure and market access.

National labor markets typically become tighter and wages rise as MICs develop, and farm incomes generally grow more slowly than non-farm incomes. Maintaining reasonable parity between farm and nonfarm incomes requires that research shift toward the development of technologies that increase labor productivity. Less favored areas also tend to get left behind and require targeted research and other public investments to reduce poverty and food insecurity among their populations. Investments that are win-win for growth and poverty reduction are needed to avoid significant tradeoffs against the interests of the poor outside targeted LPAs.

5. Strategies for Pro-Poor Agricultural Research

Chapter 4 identified several key topics for a pro-poor agricultural research agenda. These include:

1. Increasing production of staple foods in countries where food price effects are still important and/or that have comparative advantage in growing these crops. This includes most LICs, but also many MICs that have not liberalized their trade and markets.
2. Increasing agricultural productivity in many less-favored lands. Special attention is needed for heavily populated LPAs, but also some HPAs that are constrained by poor infrastructure and market access. Appropriate technologies for these areas will often have to be based on low use of external inputs.
3. Helping smallholder farms in all kinds of areas to diversify into higher value products, including livestock products, especially in countries with rapidly growing domestic markets for such products (most MICs) and/or access to suitable export markets.
4. Increasing employment and income-earning opportunities for landless and near-landless workers in labor-surplus regions. This is especially important in LICs with growing populations and land scarcity.
5. Developing more nutritious and safer foods to enhance the diets of poor people by investing in agricultural technology that reduces the price of micronutrient-rich foods in urban and well-integrated rural areas, increases physical access in remote rural areas, or increases the nutrient content of food staple crops via traditional or transgenic technologies. This is especially important for LICs where poor diet quality generates micronutrient deficiencies that impair the health of current and future generations.
6. Undertaking agricultural research in ways that are more empowering to the poor.

If these objectives could be achieved without having to trade off much agricultural growth at the sector level, this would lead to larger indirect benefits in the nonfarm economy that would contribute to further rounds of longer-term poverty reduction. In short, agricultural research must target poor peoples' problems in ways that are win-win for growth and poverty reduction. The following is a discussion of appropriate research strategies for achieving each of these objectives.

Research Strategies for Staple Food Production

Irrigated and high-potential rainfed areas will continue to be the major producers of staple foods in most countries, and improved technologies and natural resource management (NRM) practices for these areas will be critical for maintaining ample and affordable food supplies. Growth in staple food production will also be important in many less-favored lands as a way of

targeting poverty and food security (see below). In high-potential areas with abundant labor in the form of landless workers or small farms, technologies and NRM practices are needed that are employment intensive (Lipton with Longhurst 1989; IFAD 2001). On the other hand, in high-potential areas that must compete for labor in tightening labor markets, technologies that increase both labor and land productivity are required. Technologies also need to reduce production costs per unit of output so that farmers can better compete in world markets (including competing with imports) and consumers can benefit from cheaper foods and raw materials.

The Green Revolution technologies achieved many of these goals, but they have now largely run their course. There is a need for more upstream germplasm improvement work, including biotechnology. Yet at the same time, germplasm improvement needs to be integrated with better natural resource management practices to contain environmental problems that are now common in many intensively farmed areas. The more efficient use and better management of external inputs such as chemical fertilizer, irrigation water, and/or land-use diversification may lead to higher productivity and reduced environmental degradation. Such knowledge-intensive farming will require improved extension systems and greater investment in farmer education.

Focusing on staple foods production can be win-win for growth and poverty reduction when the research benefits regions that have a comparative advantage in these crops. Countries that lack comparative advantage in foodgrains but that nevertheless pursue self-sufficiency in their production may achieve greater national immunity from the vagaries of world food markets, but at the cost of economic growth opportunities. Such opportunity costs are smaller when the foodgrains are grown in LPAs rather than HPAs, and the trade-off may be worthwhile if this leads to significant gains in food security in those regions.

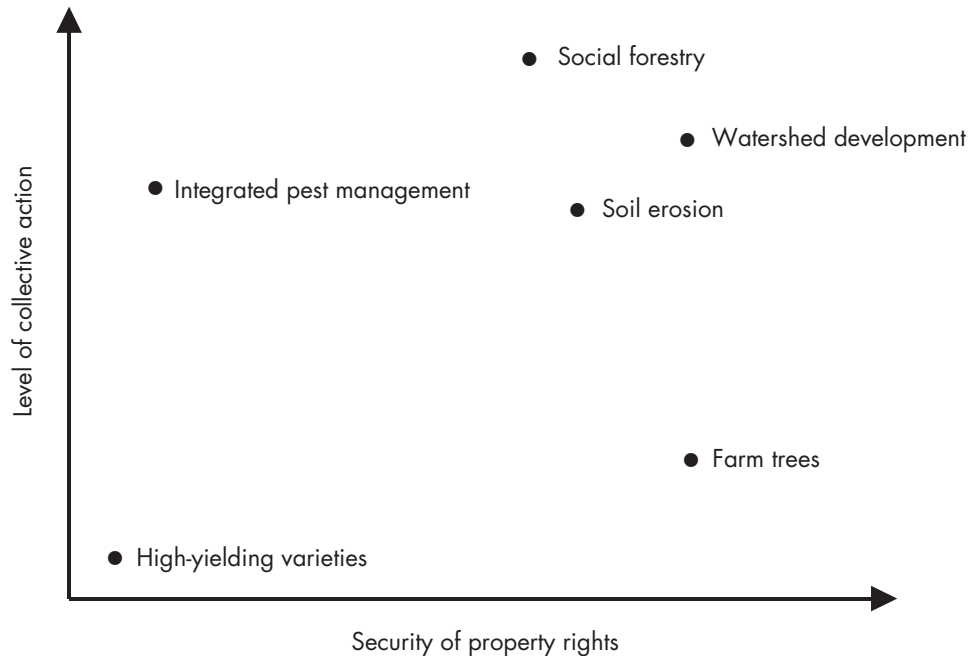
Research Strategies for Less-Favored Areas

While some types of commodity improvement work seem vital for less-favored areas—improving drought tolerance, yield response to scarce plant nutrients, food nutrient content, pest and disease resistance, and livestock health and productivity—there is a growing consensus that major productivity improvements will first come from improved natural resource management (NRM) practices and technologies. In areas of poor soils and harsh climate, NRM can lead the way in improving soil depth, organic matter, fertility, and moisture content, and eventually higher yields from fertilizers and improved varieties.

The poor infrastructure and market access that characterize many less-favored areas make the use of high levels of external inputs uneconomic, placing a premium on low external input (LEI) technologies. LEI technologies are typically labor intensive, both seasonally and in total, and this can constrain their use. Fallows and green manures also keep land out of crop production, and composting and manuring compete with household energy use for scarce organic matter. The challenge is to develop LEI technologies that boost both labor and land productivity.

Although poorer LFAs need improved technologies for food crops for subsistence and local needs, sustained increases in per capita income will hinge on diversification into higher-value agricultural products and nonfarm activities. Successful examples include dairying in India, growing olives in North Africa, and raising horticultural crops in parts of Central America (Hazell, Jagger, and Knox 2000).

A key lesson from many past research investments in LFAs is the importance of social and institutional constraints, particularly the effectiveness of indigenous property rights systems and local capacity for organizing and sustaining collective action for managing natural resources. Figure 5

Figure 5—Links between property rights, collective action, and technology adoption

Source: Knox, Meinzen-Dick, and Hazell 1998.

(taken from Knox, Meinzen-Dick, and Hazell 1998) plots increasingly secure property rights on the horizontal axis and increasing levels of collective action on the vertical axis. Some of the most successful agricultural technologies lie close to the origin in this figure. For example, the benefits of high-yielding cereal varieties (HYVs)—the lynchpin of the Green Revolution—could be captured within a single agricultural season and hence did not require secure property rights. Even sharecropping tenants with single-season leases were able to adopt these technologies. Moreover, since individual farmers could adopt regardless of what their neighbors decided to do, collective action was not necessary. These features made adoption decisions relatively simple, and they help explain why Green Revolution technologies spread so quickly and widely despite considerable diversity in local socioeconomic conditions.

But where research agendas must focus on the sustainable use of natural resources, local institutional issues become much more prominent.

Integrated pest management, for example, requires that all farmers in an area work together; the technology is not effective if some farmers spray indiscriminately or if planting dates are not synchronized. However, the returns are relatively quick, so secure property rights are less of an issue. For these reasons, IPM appears in the upper left corner of Figure 5. In contrast, planting trees on farms (agroforestry) is a long-term investment that requires secure property rights. But since trees can be planted by individual farmers regardless of what their neighbors do, “farm trees” appears in the lower right-hand corner. But many other technologies for improved NRM require both secure property rights and effective collective action and therefore appear in the upper right-hand quadrant. Watershed development, for example, requires secure property rights because it involves long-term investments in check dams, land contouring, and tree planting in water catchment areas, and it can be successfully done only if the entire community living within the rele-

vant landscape is mobilized to support collective action. If these institutional conditions are not met, the technology is not likely to be adopted and maintained, regardless of its profitability and scientific soundness.

Difficulties arise because institutions for property rights and collective action are rarely formalized in developing countries, and communities vary widely in their ability to organize and sustain such institutions on their own. Socioeconomic research has much to contribute toward our understanding of local institutions and the conditions under which they are likely to be effective. Without such knowledge, and a corresponding ability on the part of policymakers to intervene and to strengthen local institutions when necessary, many promising NRM technologies are not likely to be adopted.

NRM research for less-favored lands should build on farmers' own indigenous knowledge and practical innovations. Some NGOs have been successful in pursuing this agenda and in working with local communities to overcome social and institutional constraints. The more effective linking of formal research to these kinds of grassroots development activities could lead to real improvements in the relevance and uptake of much NRM research. But sustained growth in on-farm productivity will also require improvements in crop germplasm and disease and pest control. Without continuing improvements in knowledge and genetic resources in less-favored areas, productivity will quickly stagnate again. The potential to breed higher-yielding varieties in many less-favored lands may be constrained by the low-yield potential of the existing range of genetic material. Existing material has often been selected by man and nature for robustness under harsh and risky growing conditions. Transgenic biotechnology may prove an essential tool for achieving the wider crosses that will be needed (IFAD 2000).

Many agricultural researchers are skeptical about the efficiency of research in less-favored areas, arguing that it is better to invest in HPAs because these give higher returns to research and

contribute more to agricultural growth per research dollar. Growing conditions are seen as diverse in LFAs, and so improved technologies may not have widespread application (in contrast to Green Revolution technologies that spread over tens of millions of hectares of irrigated land). Technologies are also perceived to be more difficult and perhaps more costly to develop. There is undoubtedly some basis for these concerns, especially for commodity improvement research. On the other hand, recent evidence from India and China shows that, dollar for dollar, agricultural research investments in LFAs can outperform investments in HPAs in productivity growth and poverty reduction in some types of less-favored areas (Fan, Hazell, and Haque 2000; Fan, Zhang, and Zhang 2000).

As should be expected, the returns to additional research investments vary by agroclimatic zone and are very low for both growth and poverty in some of the most marginal zones. But the range of conditions under which research investments have significant impact is impressive (Fan, Hazell and Haque, 2000). One reason for these results is that India and China have already invested heavily in their irrigated and high-potential rainfed areas, and productivity growth has slowed in many of these regions. With diminishing returns in HPAs and relatively little research investment in many LFAs, it is not surprising that the latter should now give higher returns to research investments on the margin. But care must be taken in extrapolating these results to other countries that have invested a great deal less in both HPAs and LFAs, for example, much of Sub-Saharan Africa. In these cases there could well be some important trade-offs between sectorwide growth and regional poverty reduction from targeting research resources on the problems of LFAs.

One way to reduce the cost of research in LFAs is to focus on NRM problems that are common to a significant number of poor people—but only problems that can be scaled up from benchmark sites. The scaling up need not mean that all sites have to be homogenous, just that improved

NRM practices can be easily adapted by local people and institutions to different site-specific circumstances. The research also should involve relevant socioeconomic work to understand the social and economic constraints on adopting improved NRM practices, and partnerships need to be formed with institutions with the capacity to overcome these constraints at the grassroots level.

Research Strategies for Smallholder Farmers

As farms get smaller, it becomes increasingly important to develop technologies that increase their labor as well as their land productivity. Otherwise, they will simply be working harder and harder to achieve the same level of per capita income.

In order to maintain their incomes, smallholder farms will need to diversify beyond traditional crop production into profitable activities that are compatible with their diminishing land/labor ratios. Countries with rising per capita incomes offer expanding opportunities to diversify into livestock and horticultural production to meet rapidly growing domestic demands. These activities typically give high returns per unit of land and are labor-intensive, and hence well suited to small-farm conditions. Such diversification is already happening in many countries, especially in Asia and Latin America. Rising per capita incomes are also associated with expanding rural nonfarm economies, which offer opportunities for smallholder farm families to diversify into nonfarm employment or into nonfarm businesses. In Southeast Asia, small farmers seem to be following the development pattern that occurred in Japan: becoming part-time farmers with regular employment in nonfarm, often industrial, occupations (Rosegrant and Hazell 2000).

The opportunities for income-enhancing diversification are much more constrained in countries with low and stagnant per capita incomes. In these cases, attention needs to be given to devel-

oping cash crops for export or expanding opportunities for seasonal migration to cities. Other income-augmenting measures include creation of rural processing facilities to enable higher-value-added from agricultural output.

Targeting small rather than large farms will complement agricultural sector growth if small farms are at least as economically efficient as large farms. An impressive body of empirical evidence confirms that land productivity is inversely related to farm size in many developing countries (see Heltberg 1998 for a recent review). One reason for this is that hired labor is less efficient and more costly to manage than family labor, giving smaller farms a competitive advantage. Another reason may be the higher management intensity that is possible on smaller farms. But because small farms use more labor-intensive technologies, their average labor productivity is also lower. As countries develop and agriculture must compete with higher-paying nonfarm employment, mechanization and more capital-intensive farming methods become important to increase labor productivity. This requires that farms become bigger. There is little hard information about when this crossover occurs, and it is likely to vary with the rate of rural population growth (which slows the transition), with credit subsidies and other agricultural support policies (which often encourage premature mechanization), and with opportunities for income diversification into nonfarm activities in rural areas (which can have mixed effects because greater opportunities encourage continued part-time farming by small farmers but also raise wage rates). Nor does a crossover necessarily occur for some employment-intensive types of farming—for example, high-value horticultural crops and intensive livestock production. It seems likely that the crossover is important for foodgrain production by the time countries reach middle-income status, but small farms may retain their competitive edge indefinitely for some types of horticultural and livestock farming.

Another concern is that, with increasing rural populations but scarce land, small farms may

eventually become too small and fragmented to be efficient. Carter and Wiebe (1990) have provided evidence from Kenya showing that profits per hectare decline when farms get too small. It is premature to draw any definite conclusions about this concern, and, even if true, it is likely that small farms first lose their competitive advantage for growing foodgrains rather than labor-intensive livestock and horticultural products.

Even though small farms are generally the more efficient producers, this advantage may be offset by problems in reaching markets. Because small farms typically trade only in small quantities, both inputs and outputs, they cannot command the same price advantages as larger farms dealing in greater bulk. They are also less likely to have the same access to market information and contacts. Such disadvantages can be offset by cooperatives, contract farming, and other marketing arrangements, but these often introduce additional costs and challenges. Resolving such marketing problems—once the mandate of now-disbanded marketing parastatals—may be critical to achieving greater complementarity between targeting smallholder farms and agricultural productivity growth.

Research Strategies for Landless Laborers

Landless laborers are difficult to reach through agricultural growth except through the labor market (both locally and through inter-regional migration) and the rural nonfarm economy. In irrigated and high-potential areas, agriculture's employment elasticity has shrunk in the post-Green Revolution era in many countries. In India, for example, the employment elasticity has fallen from about 0.7 in the 1970s to about half that level today. This means that a 1 percent increase in agricultural output generates a much smaller percentage of additional employment than before. The recent removal of credit subsidies and policy distortions as part of structural adjustment and market liberalization

reforms in many countries may discourage inappropriate investments in mechanization and help shift agriculture toward more employment-intensive patterns of growth, helping landless and near-landless farmers. Increased investments in improved natural resource management in less-favored areas should also help create additional employment because many of these investments are labor intensive. In countries where rising per capita incomes are spurring demand for livestock and horticultural products, agricultural employment is likely to grow as farms diversify into these activities.

The landless also can benefit from types of livestock production where animals are kept in stalls or cages or fed from common property grazing resources and purchased feeds (for example, poultry, rabbits, goats, and dairy cows). Rehabilitation and better management of common property resources in general can also help the landless, since the use of these resources is often an important element in their livelihood strategies.

Increasing employment and labor productivity through improvements in labor and capital markets is also good for economic efficiency and offers win-win opportunities. Targeting research on the own-agricultural activities of landless workers probably adds little to overall agricultural growth rates in the short term, but it could lead to longer-term growth by increasing worker productivity and the economic contributions of their children (see next section).

Research Strategies for More Nutritious Foods

Conventional research approaches can help improve productivity and lower the price of non-staple crops that are rich in micronutrients. This potentially powerful indirect effect should be seriously considered in regions that experience high micronutrient deficiency and are poorly linked to international or domestic markets. The following approaches should be considered.

New Technology for Small-Scale Home Gardening of Micronutrient-Rich Food

A recent review of food-based interventions to combat vitamin A deficiency points to the potential of home gardening combined with promotional and education interventions. With regard to iron, production and education interventions to increase the supply and intake of iron from plant foods have not been as popular as those for vitamin A. Experience with food-based approaches to increase production and/or consumption of heme or non-heme iron-rich foods is limited, but some lessons are clear. In addition to the well-known problems of bioavailability with iron from plant sources, the experience with animal production suggests trade-offs between increased income from selling home-produced animal products and increasing one's own consumption of these products to improve dietary quality. Similar to home gardening interventions, a strong nutrition education component is critical to achieving improved dietary diversity through animal production interventions.

Postharvest Technologies

Postharvest activities can affect nutrient availability by increasing the general use of nutrient-rich foods (for instance, beta-carotene-rich varieties of sweet potatoes), increasing the nutrient density of foods consumed by infants, and decreasing nutrient losses from the processing of widely available foods. Postharvest activities include storage, commercial processing, in-home processing, and preparation. Food processing includes physical processes (heat/cold treatment, mechanical separation such as milling, and reduction of water activity), chemical processes (addition of acid, alkaline, oxidizing, and reducing agents), enzymatic processes (hydrolysis of proteins and inactivation of toxins), and biological processes (fermentation and germination) (WHO 1998). A good example of work that has the potential to increase the general use of nutrient-rich foods via processing is provided by the work of the

International Potato Center (CIP) with sweet potatoes. A series of papers have been written that describe the technical and economic feasibility of deriving and using sweet potato chips and flours in chapati and bread processing, as well as consumer acceptance (Hagenimana and Owori 1997a and 1997b). The goal of this work is mainly to reduce the costs of production and the cost to the consumer. Sweet potatoes performed well in every area. The successful application of such techniques to orange- and yellow-flesh varieties that are richer in beta-carotene has directly helped improve nutrition in Kenya (Hagenimana and Oyunga 1999).

Breeding Techniques to Improve the Nutrient Content of Staples

There are several ways to improve the nutrient availability of food staples: (1) increase the density of micronutrients in the grain, (2) decrease the density of factors that inhibit human absorption of micronutrients already in the grain, and (3) increase the level of promoters of human absorption. Breeding methods can be conventional or transgenic.

The CGIAR micronutrients project involving the International Rice Research Institute (IRRI), the International Center for Tropical Agriculture (CIAT), CIP, and IFPRI is beginning to produce some promising results (Bouis, Graham, and Welch 2000). First, two high-yielding, high-iron rices were identified among improved lines already being tested by IRRI and now being subjected to human feeding trials. Second, 24 selected genotypes of beans from CIAT were found to have substantial variation in iron concentration and a constant level of bioavailability. The development of low phytic acid mutants of maize and other cereals for use in food and feed is another approach to improving the micronutrient content of staples. An important advantage of low phytic acid mutants is that the bioavailability of a range of minerals may be improved. Yields of the best low phytic acid lines, first developed in the mid-1990s, now range between 5 and 15 percent

below those of the highest-yielding commercial varieties. Because of the benefits for nutrition, low phytic acid crops may have higher total benefits to the poor, although the rate of adoption will remain a drawback as long as yields are compromised (Raboy 2000).

Enhancing the nutrition status of the poor will lead to additional productivity growth (both in agriculture and other activities) today and in future generations. Undernutrition involves serious economic costs. Both stunting and anemia are known to lower productivity in physical labor. Adults who are moderately stunted are 2 to 6 percent less productive, and those who are severely stunted are 2 to 9 percent less productive, than those of normal stature (Horton 1999, using estimates in Haddad and Bouis 1991 and Alderman et al. 1997). Iron deficiency anemia is associated with a loss of productivity of 5 percent in light blue-collar work and 17 percent in heavy manual labor (Ross and Horton 1998).

Evidence suggests that childhood stunting and iron deficiency, as well as maternal iodine deficiency, are also associated with lower cognitive outcomes in children and hence lower adult productivity in the next generation. The effects on adult earnings and productivity is estimated at 10 percent for low-height-for-age (from an older study by Selowsky and Taylor 1973), 4 percent for childhood anemia (Ross and Horton 1998), and 10 percent per child born to a mother with goiter (Ross 1997). These losses are conservatively 2 to 3 percent of GDP in low-income countries. In South Asia, the estimated losses associated with iron deficiency alone are estimated to be \$5 billion per year (Ross and Horton 1998).

Technologies that improve the nutritional content of the foods that poor people eat need not involve trade-offs with other desirable traits. Researchers at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), for example, concluded some years ago that breeding for high protein and lysine content in food grains was not a priority because calorie consumption was a more severe problem for the poor

than low protein or lysine consumption in South Asia's semi-arid tropical areas. As a result, breeding for high yield was the best way to help poor people and there was no trade-off between efficiency and poverty alleviation goals.

However, this is not so clearly the case in breeding for greater micronutrient content, such as iron and zinc, for regions where poor people suffer from serious deficiencies. Such breeding work runs the risk of drawing resources away from other objectives such as strengthening tolerance to various stresses. Even so, the cost is likely to be much lower (at least for iron and zinc) than for a capsule program that has to be sustained on a long-term basis (Ruel and Bouis 1998).

Research Methods that Empower the Poor

Participatory research, in which poor people play a role in setting the research agenda and carrying it out, has potential to make agricultural research more effective in empowering poor people. It can give them more influence over the research system to address their needs and provide them with the skills needed to solve many of their own problems.

Participatory research is still new, and there has been little attempt to assess its impact on agricultural productivity or poverty reduction. Initial attempts at participatory research have given greater priority to involving poor people in evaluating new technologies (such as specific traits of improved varieties) than in setting priorities for research itself (such as which kinds of varieties to develop, and for what types of crops, regions, and farmers). Involving farmers in problem diagnosis and field-testing of technologies can provide useful information to researchers and result in more useful products for farmers (Farrington and Martin 1988). Using participatory research to promote empowerment as a direct goal requires working with communities that are organized and skilled in working together, solving problems, and resolving conflicts. Kerr and Kolavalli (1999)

argue that “participatory research should go hand-in-hand with participatory community development that can help improve access to credit and markets and can teach local people the skills they need to organize themselves, analyze and solve problems as a group, and resolve conflicts.”

Increasing pressures on research organizations to improve their effectiveness in reaching the poor will lead to increasing collaboration with farmers. But Kerr and Kolavalli (1999, p. 137-138) identify several constraints:

More participatory research requires multidisciplinary work that may be difficult to organize; this was a constraint in earlier farming systems research (Farrington and Martin 1988). Some scientists are reluctant to learn from indigenous knowledge, and economists shy away from participatory methods because they do not always yield quantitative data. Scientific journals are less receptive to research based on participatory than traditional methods. As a result, major changes are still needed in

both researchers’ perceptions and the incentives that guide them. Another constraint is that initial costs of participatory research can be high because travel and training budgets rise. In a project to develop pest control measures in Ghana, farmer participation increased project costs by 66 percent and accounted for 80 percent of researchers’ time (Magrath et al. 1997). However, the Rwanda case shows that the extra cost can lead to higher returns by reducing the time needed to identify promising technologies. The cost per variety released actually fell in the Rwanda case (Sperling et al. 1993). Also, developing the farmers’ own capabilities in developing improved pest management systems, or conducting field trials, or even breeding can be a cost-effective way to adapt technology to local needs where conditions are spatially diverse. Where participation may mean the difference between success and failure in developing technologies, there are no cost trade-offs.

6. The Role of Public Research and Extension Systems

Public research and extension systems will have a key role in implementing the pro-poor agricultural research strategy described in the previous chapter. Because targeting the poor is not always win-win for growth and poverty alleviation, countries that can afford large research budgets, or enjoy significant private-sector investment in productivity enhancing research, will be best placed to undertake this agenda. Where the trade-offs are high, it is appropriate to consider alternative policies for poverty alleviation. Technology is only one instrument for helping the poor, and it is not always the most effective one. Its role must be seen within the broader context of rural development and grassroots development efforts.

Where productivity trade-offs exist but are not overwhelming, targeting research can sometimes offer more cost-effective and long-term solutions to poverty than alternative interventions. For example, research to improve soil nutrient and water management practices or to develop more drought-tolerant cereal varieties might lead to substantial long-term savings in relief aid in many poor, drought-prone areas. In these cases, the trade-off against agricultural productivity growth may be less important than the cost savings achieved in alternative relief programs, especially if government and donors can be persuaded to allocate some of those savings to additional agricultural research investments.

If public research and extension systems are to be effective in undertaking targeted pro-poor research, they will also have to make some institutional adjustments. Their past successes lay in developing and spreading Green Revolution technologies in high-potential areas. Because yield

ceilings had already been reached and were in need of basic biological breakthroughs, and because crops were grown in monoculture systems under homogenous conditions with good access to markets, the new technologies could be widely adopted with little if any local adaptation.

But as discussed in previous chapters, the challenges facing public research and extension systems today are rather different. In irrigated and high-potential areas, crop diversification and improved environmental management have become key challenges for small and large farms alike, and the problems facing less-favored lands are much more diverse and location-specific and involve changes in complex natural resource management systems that have been developed over generations to cope with uncertain rainfall and weather conditions, poor and often fragile soils, and the high costs of external inputs, given poor market access. Moreover, research needs to be undertaken in more participatory ways if it is to become more effective in empowering the poor. At the same time, public research systems also need to become more engaged in biotechnology research to ensure that at least part of its potential is used to enhance agricultural growth and to help poor farmers.

To meet these challenges, there is a need for a more client-oriented, problem-solving approach throughout the agricultural research system, an approach not limited to a particular kind of technology or a particular type of agriculture or zone. This approach will often translate into a need for more on-farm research under conditions that are difficult and diverse. Not all of the technological challenges facing poor people will be solved by

more on-farm work; biotechnology conducted in a strict laboratory environment may be critical, for example, in raising yield ceilings or for improving drought tolerance. However, even biotechnology will be more effective if it addresses priorities based on a client-oriented, problem-solving approach that draws many of its insights from interaction with farmers.

Institutional reforms are necessary to change incentive structures within public research and extension systems so that scientists and extension officers are responsive to the needs of their clients. But to be effective, these changes will need to extend to all levels of management (Byerlee and Alex 1998). The kinds of changes needed in public agricultural research and extension systems will also require the forging of new partnerships between the public system and NGOs, private-sector firms, and farmers.

Private seed companies and input suppliers are playing a larger role as many countries liberalize and privatize their agricultural input markets. Many of these companies not only develop improved products of their own (including undertaking agricultural research), but also advise farmers about the use of products they sell. NGOs have also become important actors in spreading natural resource management practices regarding soil and water management, watershed development, and social forestry. They have a particular advantage in helping communities take collective action to implement improved natural resource management practices at the landscape level (Kerr et al. 2000). Farmers, including smallholder and women farmers, also need to be actively involved in the design and evaluation of research intended for

their farming conditions. Participatory research methods are proving to be a fruitful way of achieving this goal (Kerr et al. 2000).

Because of the public-goods nature of much agricultural research and extension, market forces alone will be insufficient to integrate the roles of the public and private sectors and NGOs and make them fully accountable to their clients. New institutional mechanisms will also be required. Competitive research grants offer one interesting approach, particularly if they are open to all relevant public, private, and NGO agencies, and if farmers (including poor farmers and women) are represented in the decisionmaking process (Farrington and Martin 1998). Local research committees composed of relevant stakeholders show some promise as a device for setting research priorities for the public sector (Alsop 1998).

Even as agricultural research and extension systems are being asked to take on more diverse and difficult challenges, their budgets are being cut in many countries (Pardey and Beintema 2001). National agricultural research systems (NARS) in Africa have been particularly affected, and the availability of resources per scientist has fallen sharply. On average, developing countries spend about one half of 1 percent of their agricultural GDP on public research, which is much less than the 2 percent averaged by the industrialized countries. If new technologies are to be developed to address the poverty and environmental problems of developing countries, and to enable them to capture some of the potential benefits of biotechnology, then there is an urgent need to increase available funding and to implement needed institutional reforms.

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