

MODULE 4

Agricultural Research within an Agricultural Innovation System

OVERVIEW

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EXECUTIVE SUMMARY

Investing in agricultural research within an AIS framework complements the traditional internal focus on capacity and research priorities with an external emphasis on better articulation of client demand and effective institutional partnerships. Agricultural research as a producer of new knowledge requires effective institutional arrangements to apply that knowledge. The types of organizations and nature of these partnerships in the generation of innovation will depend on the market orientation of the agricultural sector and private investment in agro-industry. In urban and transforming economies, these institutional partnerships will tend to focus on research linkages to agricultural input or processing industries, often within the frame of public-private partnerships, including technology transfer arrangements, and often facilitated by public financing arrangements. Such research linkages to the private sector and other actors will tend to be organized around clusters, and financing will often be in the form of competitive grants with cofinancing from the private sector.

In agrarian economies, on the other hand, external connectivity of research is primarily through bridging organizations, particularly extension services, farmer associations, trade associations, and NGOs, and farmer demand is articulated through nonmarket mechanisms with farmer

representation. The latter tend to involve novel organizational arrangements, such as farmer councils and innovation platforms, new methodologies, organizational change within research institutes, and financing arrangements that support the increased transactions costs inherent in improved external connectivity. Farmer participation in the codesign of innovations is characteristic of these organizational arrangements, and it may be facilitated by innovation brokers. Financing is almost solely based on public sources and will tend to be organized around research foundations or agricultural research councils. There is an inherent tendency for research within an AIS to focus on market-driven applications, often within a value chain framework, and particular strategies are required to ensure that research continues to contribute to the reduction of rural poverty.

RATIONALE FOR INVESTMENT

As the globe enters a period of increasing constraints on land, water, and nutrient supplies, a tight balance between food supply and demand, and the certainty of climate change, new knowledge from agricultural research systems will be essential to maintain growth in agricultural productivity and in world food supplies. Locating agricultural research within an AIS is a means of heightening the performance of research systems through improved articulation

with demand, more effective, better-differentiated institutional partnerships, and better market integration.

An innovation systems framework adds a set of new dimensions to the investment in agricultural science and technology. An AIS framework focuses attention on: (1) an expanded range of technologies (particularly postharvest and mechanical) provided by a differentiated set of suppliers; (2) demand responsiveness, particularly better connectivity and interaction of agricultural research with actors beyond farmers; and (3) adaptation to and facilitation of organizational innovations in credit, markets, insurance, farmer groups, and extension services.

The reframing of technological innovation coincides with the emphasis on market-led approaches for smallholder development, which have emerged in the wake of structural adjustment and market liberalization in the 1990s. Orienting research to markets, often through work in specific value chains, has become a principal vehicle for delivering new technologies and for combining them with the organizational and institutional innovations that so often accompany technical change in the agricultural sector.

In this sense, an AIS approach represents a relatively evolutionary form of institutional change in agricultural research, with a particular focus on enhancing the research system's external responsiveness. Yet improved responsiveness in the short term must be balanced with the investment strategies needed over the long term for a research system to be productive. In the process of balancing these short- and long-term imperatives, research organizations will arrive at a better alignment between internal research capacities and external partnerships and consortiums, increasingly with the private sector.

PAST EXPERIENCE IN ORGANIZATIONAL CHANGE IN AGRICULTURAL RESEARCH

Investment strategies for agricultural research over the past three decades have gone through a series of approaches, often requiring major organizational restructuring. Research restructuring has been much more pervasive in small countries than in large, which has given systems such as EMBRAPA in Brazil continuity in addition to significant levels of investment. The sections that follow describe these various approaches to investing in agricultural research.

Building national agricultural research institutes

Broadly defined, the 1980s and early 1990s were the period of the national agricultural research institute (NARI), when

research units distributed throughout ministries of agriculture and other ministries were brought under a single, independent administrative structure. The assumptions ruling this restructuring were that economies of scale and scope could be achieved in agricultural research, budgetary resources allocated much more efficiently, and personnel policies freed from public civil service bureaucracy. Large countries such as Brazil and India developed a complex federal and state system of national research institutes, state agricultural universities, and state research institutes. Donor investment in agriculture was at an historical high, at least in percentage terms. The CGIAR network of international agricultural research centers expanded, and donors led by the World Bank and USAID funded programs that focused on training, infrastructure development, and program formulation within the newly formed NARIs.

From national research institutes to research systems

The dominance of the NARI gave way quite quickly in the late 1990s to reform based on the development of more pluralistic, decentralized systems, in which research funding and execution were separated, often through a competitive grants modality. The intent was to move away from reliance on a single research institution and toward the development of a broader-based national agricultural research system (NARS). At the same time, support for agriculture in aid budgets was declining, and domestic fiscal budgets came under pressure from structural adjustment. The rapidly growing Asian economies could support agricultural research from expanding tax revenues, and in Latin America market liberalization allowed greater participation of the private sector. In Africa, however, the reform of NARIs took place amid severely restricted budgets, often within a small-country context. The World Bank remained virtually the only donor investing in national agricultural research. Selective investment caused a few relatively strong NARSs to develop, leaving a majority of systems with limited capacities.

Decentralization and participatory research

This period also saw the rise of participatory research and the recognition that NARIs had to become more responsive to demand. Improved responsiveness was the principal justification for reforms that decentralized management within NARIs and created autonomous research councils. The councils, which often had farmer representation,

now controlled the funding decisions (World Bank 2006), but their effectiveness varied greatly. Many had a narrow representation of stakeholders, consisting primarily of ministerial representatives or researchers, and their research prioritization process was not necessarily consistent and rigorous. The councils often had little influence on the policy process and how research was conducted. Many did not separate funding allocation and implementation effectively (see module 1). Decentralization was already a feature of large federal systems, but it involved significant tradeoffs in small systems. Scale economies in areas such as plant breeding were sacrificed, and operational budgets were directed to more adaptive research.

Shifting funding

Shifting funding to competitive grants had different impacts depending on the capacity of the research system. In larger systems with strong capacity, competitive mechanisms were used to improve research quality. Larger research systems used competitive grants to provide funding based on scientific peer review. They particularly aimed to: focus scientists' efforts on high-priority research or new fields of expertise; improve the relevance and quality of agricultural research, extension, and training; promote research partnerships and leverage research resources; and help to develop a more efficient and pluralistic research system (World Bank 2010). In smaller research systems, where financial constraints already limited core capacity, competitive grants were often used as a mechanism for farmers to articulate their demands for research more clearly, and farmers would participate in the grant review process. Such mechanisms reinforced the shift to adaptive research.

The use of competitive grants tended to undermine long-term strategic planning, however. A new crop variety can take ten years or more to develop; so does a locally adapted conservation agriculture system or a system to manage animal disease. The longer-term nature of agricultural research has produced significant debate on the extent to which research systems can respond to demand by allocating resources (often based on contestable funding mechanisms) to applied research as opposed to allocating resources (core funding) through longer-term strategic planning in relation to priority needs in the agricultural sector.¹ According to World Bank (2009, xii–xiii), a review of four World Bank projects in Latin America that employed competitive grant schemes for agricultural research,

A principal lesson concerns the importance of strengthening the capacity of research organizations, not just financing

research. Competitive funds can be an important vehicle for research financing and have a strategic role to play in piloting new ways of working, or focusing research on new topics; but they are most likely to make a sound and lasting contribution when they complement a relatively strong public sector framework for research (in this respect, prospects were brighter to begin with in Brazil and Colombia than they were in Nicaragua and Peru). Public funding is essential for agricultural innovation systems and private funding complements rather than substitutes for higher levels of public funding.

In Latin America, small-country systems became much more reliant on research outputs from CGIAR centers and spillins from private sector sources globally. Some countries even terminated public agricultural research altogether. Efforts to building core research capacities in sub-Saharan Africa, Central America, and the smaller South American countries got lost during this period of restructuring. In Africa, core research capacities remain largely underdeveloped after three decades of experimentation. While African governments committed themselves to increasing investment in agriculture to 10 percent of the overall national budget, by 2009 only a few countries had met the target.²

Limited operational funding

Operational funds are vital to research that results in interaction with rural communities outside the research station (on-farm adaptive research, multilocal testing networks, participatory plant breeding, disease surveillance programs, and soil fertility trials, for example). Because soil and biotic constraints are more severe in farmers' fields, carrying out research in farmers' conditions increases the relevance of the results.

The lack of operational funds is the first most binding constraint on the productivity of agricultural research, and the shortage of funds was particularly binding in Africa, where it limited the demand articulation that decentralization was supposed to provide. Ensuring access to operational funds is essential for research performance, but where budgets are highly constrained, such funding is the first to be cut to assure salaries, station running costs, and maintenance of core resources such as germplasm banks. Productive scientists are usually those who obtain external funds at the expense of the integrity of the overall research program.

The small-country problem

There remained a pervasive sense, especially among bilateral and multilateral investors, that agricultural research in the

public sector was not meeting the performance standards that were expected. This perception tended to apply to research systems in smaller countries with little private sector capacity in agricultural research and with systemic market constraints.

Agricultural research in this context faces what is best termed a “small-country problem,” in which limited market size, constraints on achieving economies of scope and scale, constrained fiscal budgets, and ineffective farmer demand for new technologies significantly limit the productivity of research. Research capacity is needed even to borrow technology, and in some conditions, technology can rarely even be borrowed. In sub-Saharan Africa, the potential for international spillins is very often limited because of the crops that are grown (they are not widely grown elsewhere) and the particular constraints on farmers’ productivity (Pardey et al. 2007). Improving institutional performance under such circumstances is difficult, but the justification for investing in research in agrarian economies remains very strong, because agriculture remains the engine of growth for the overall economy.

Support to subregional research

One approach to the small-country problem, particularly in Africa, was to organize agricultural research at the subregional level to achieve scale economies and organize spillins efficiently. Since the late 1990s, many donors have shifted funding into subregional research organizations and the regional apex body (the Forum for Agricultural Research in Africa) and away from NARSs (see TN 3 on regional research). Initially subregional research organizations became a mechanism for coordinating regional research undertaken by CGIAR centers, but since the mid-2000s they have been a mechanism to “retail” research grants to national programs. The lost connection with international research centers left no framework to develop scale economies in these regional approaches, although two large projects funded by the World Bank (the East Africa Agricultural Productivity Project and West Africa Agricultural Productivity Project) were partially designed with that goal in mind. In Africa, the centralization represented by subregional organizations further diminishes farmers’ ability to articulate demand (Sumberg 2005) in a context where the prospect of spillins is quite small, agroecologies extremely diverse, and the commodity structure of the food system very heterogeneous (Pardey et al. 2007).

Key lessons from reforms

Possibly the most important lessons drawn from attempts at restructuring agricultural research are:

- One size does not fit all. Context and path dependence matter in the design of an agricultural research system.
- The productivity of agricultural research differed significantly between large and small countries and between countries with well-functioning market economies and those without.
- Some period of consolidation was necessary for researchers to adapt to reorganization.
- Leadership was a crucial factor in NARIs that performed well.
- The lack of sustainable funding and weak capacity continued to limit the performance of agricultural research institutes in small countries.

The shift in investment in agricultural research from a focus on NARIs to a focus on NARSs and subregional research organizations took place as markets were liberalized, civil society expanded, and collective action increased in rural economies. To a significant degree, these developments were preconditions for investing in agricultural research within an AIS framework. One framework for needs assessment for agricultural research systems argues to (1) get the resources right, (2) get the priorities right, (3) get the linkages right, and (4) get the incentives right (Howard Elliott, personal communication). In an AIS, the investment framework shifts to focus on linkages and incentives and on identifying where further organizational change is oriented to external responsiveness. Whether this reorientation at this early period in the development of AISs can produce self-correcting change in both resource and capacity constraints is still largely untested, at least for research systems in small countries. The rest of this overview will focus on the evolving practice of undertaking agricultural research within an AIS framework.

RESEARCH WITHIN AN AIS

Knowledge and information are the engines of an AIS, and a market economy provides the incentives to search for improved products and processes that lead to overall gains in productivity within the agricultural economy. In many (if not most) agricultural economies in the developing world, however, resources, capacity, and market constraints retard the development and functionality of innovation systems

for agriculture. The *World Development Report 2008* (World Bank 2007) differentiates between agrarian, transforming, and urbanized economies:

- *Agrarian economies* are almost always relatively small, mostly in sub-Saharan Africa, depend primarily on staple food crop production, and rely on agriculture for their economic growth. Their agricultural markets are not well integrated, transport and logistics are costly, and private investment in rural areas is still limited.
- *Transforming economies*, including China and India, are mostly in Asia, where economic growth is now led by the industrial sector and the economy is rapidly urbanizing. Growing urban demand, especially for higher-value products such as livestock and horticultural crops, is resulting in structural shifts in the agricultural economy. Even so, large areas of the rural economy still have high poverty rates and are not integrated into the growth process.
- *Urbanized economies* have most of their population in urban areas, are primarily located in Latin America, and the agricultural sectors are well integrated into global markets. Poverty is principally an urban problem.

Compared to the agrarian economies, transforming and urbanized economies invariably have better developed transport infrastructure and agricultural markets, a larger and more vibrant private sector, deeper R&D capacity, more effective agricultural institutions, and greater investment in ICT. These in turn are some of the preconditions for more functional innovation systems, particularly systems driven by expanding opportunities in more dynamic agricultural markets.

The sections that follow describe the contrasting roles of research and AISs in well-functioning market contexts and underdeveloped market contexts. A discussion of AIS approaches used to promote technological innovation is followed by an overview of key policy issues related to agricultural research in an AIS context, evolving areas of investment, and approaches for monitoring, evaluating, and scaling up agricultural research within an AIS.

Well-functioning markets and AISs

The functionality of an AIS rests on increasing connectivity within a widening organizational “matrix” in the agricultural sector. A growing private sector, increasing commoditization, and expanding market opportunities lead to an

increasing array of organizations to promote their interests, most often in relation to government policy but also in relation to establishing norms of operation within their respective subsectors.

The proliferation of formal seed, chemical, and fertilizer associations, agroprocessing associations (for example, the Thai Tapioca Trade Association), animal feed milling associations, and commodity organizations (in module 1, the overview as well as TNs 3 and 4 provide examples) (from wheat and oilseed milling to horticultural exports) reflects the higher and more concentrated end of the value chain. In higher-value commodity chains, farmer organizations usually form around a particular commodity and often build off of cooperatives (dairy industries and the Colombian coffee federation are two examples). Such an organizational matrix balances competition with cooperation and organized collective action to further the interests of the subsector. Information flows are good: The subsector’s needs are easily articulated, and appropriate institutional linkages and arrangements formulated, usually on a task basis.

At this stage of market development in the agricultural sector, an AIS is self-organizing. Public sector research has to be very responsive and flexible indeed, primarily to needs articulated through input-supply or agroprocessing firms, or it will quickly become an anachronism.

Innovation systems and the shift to a market context

As farmers integrate into the market economy, they rely more on inputs as a source of increased productivity and sell an increasing percentage of their production. Often they first diversify into higher-value crops and then specialize in particular production activities. Such intensification is facilitated by a widening array of innovations provided through markets for inputs and agricultural services. These innovations increasingly respond to changing urban demand, both for specific commodities and for specific quality characteristics in commodities.

Public agricultural research has continually wrestled with the issue of how to be more responsive to demand and, in a modernizing agricultural economy, how to balance farmers’ needs with improved consumer acceptance. For example, in plant breeding and seed systems, seed companies are the translation point in the seed value chain between farmers’ production constraints (how to produce a seed that farmers will buy) and consumers’ quality requirements (if consumers and marketing agents want the product, then their

preference feeds back to farmers in the form of a price premium for the commodity/variety). Plant breeding innovation by seed companies bridges the interests of producers and consumers, but only within a functioning, competitive seed market.

Private research capacity develops principally where agricultural markets function well, as in Latin America and Asia, especially in the large countries with their large markets. As agricultural economies modernize and the private sector becomes more active in funding its own agricultural research, innovation turns more to the application of frontier science, and public research tends to support private companies by developing new products (hybrid rice, for example) or supporting private sector research.

In agriculture, molecular biology and genomics represent this kind of frontier science, which is often supported through competitive grant schemes and in which universities often have a comparative advantage. For example, India's National Agricultural Innovation Project (NAIP) has a competitive grant scheme that funds innovation clusters around more basic research with potential applications of interest to the private sector. In Thailand, similar efforts are led by the Ministry of Science and Technology through its National Innovation Agency and BIOTEC program; they also focus on funding clusters of research and related applications. In addition, BIOTEC has set up two independent research programs, the Rice Gene Discovery Unit (applications of genomics and molecular biology in rice breeding) and the Cassava and Starch Technology Research Unit (molecular approaches to understanding starch synthesis and quality, with a particular focus on the Thai starch industry).

In these cases, public sector research is increasingly divorced from farmers as the primary clientele, relying instead on input markets as the mechanism for articulating farmer demand. Occasionally the interests of farmers and input companies do not coincide, however, as exemplified by the tensions surrounding pesticide use and the scaling up of integrated pest management programs in Asia.

Under these market-driven conditions, investments in public agricultural research tend to focus more on institutional innovations that reinforce the ties between research and the private sector. IPRs are emphasized, for example, often as much to ensure open access to publicly generated innovations as to protect innovations developed in the private sector. IPRs are often the basis for contractual arrangements in public-private partnerships. This connectivity can be reinforced by competitive grants that insist on public-private partnerships, brokers that can mediate between

public research and subsector needs, science parks adjacent to research institutes that focus on areas of joint R&D, and venture capital funds that invest in developing products and markets based on research innovations.

Other areas of applied agricultural research are less well served by the private sector, however, and constitute more classical public goods, such as pulse and grain legume breeding, crop disease surveillance, development of forages for ruminants, and especially crop management and natural resource management research. Agricultural research institutes within dynamic agricultural sectors have to strike a balance between the more basic research that complements the private sector's interests and the more applied research that farmers need. This balance will become even more important with the increasing focus on using water and nutrients efficiently and reducing environmental externalities in production systems.

Even *transforming agricultural economies* have a role for public sector research in lagging rural areas with high poverty rates, usually associated with underdeveloped markets. External connectivity in these cases usually focuses on bridging organizations, particularly NGOs and extension services. In these cases, the AIS essentially reduces to the traditional partnerships between farmers, research, and bridging organizations, but those organizations provide a range of services beyond advisory services, including savings and credit schemes, farmer mobilization, and improved market access.

India's NAIP is an example of a funding program that stratifies its platforms or clusters based on relative market development and associated rural poverty. In more commercialized areas, NAIP's platforms involve public-private partnerships, and in lagging areas they involve traditional research and bridging organizations.

For smaller research institutes, this kind of stratification creates a dilemma. Should they focus on the more commercial areas and associated partnerships or focus on the lagging areas? The potential for innovation will be higher in the commercial areas, but the public interest may reside with the lagging areas. The tendency within an AIS will be toward the former, whereas the public role will in most instances lie in the latter.

Research within underdeveloped market contexts

The more agrarian economies, particularly those in sub-Saharan Africa, can be characterized as primarily dependent on smallholder, rainfed agriculture. Farmers face conditions of incomplete and unintegrated input and output markets,

asymmetric information, and high transaction costs. Markets for insurance and credit are virtually nonexistent.

COMBINING TECHNICAL AND INSTITUTIONAL INNOVATIONS. For agricultural research to be effective under these conditions, technological innovations must usually be combined with organizational and institutional innovations, primarily to compensate for the lack of markets as an organizational impetus for innovations. Moreover, innovations tend to follow more orchestrated trajectories (Rajalahti, Janssen, and Pehu 2007)—in other words, the innovation process tends to be facilitated by external actors, and technical innovations are often integrated with organizational innovations.

For example, the deployment of improved sorghum varieties, microdosing of fertilizer, and pit technology for water harvesting in Sahelian countries becomes much more profitable for farmers to adopt if farmers form associations around warehouse receipt systems. In this way, technical innovations are combined with organizational innovations that compensate for incomplete input and credit markets and foster efficient bulking for output markets. Orchestrated trajectories are further facilitated by policy changes that legalize banks' acceptance of warehouse receipts, often initially with a loan guarantee program.

BRIDGING ORGANIZATIONS. Where markets are incomplete and unintegrated, bridging organizations—particularly extension services, farmer associations, trade associations, and NGOs—link the research and knowledge domain with the production and emerging market domain. These organizations deliver and adapt research products as well as develop supporting organizational innovations that provide greater access and efficiency in processing and marketing.

Bridging organizations are an imperfect mechanism for articulating consumer and farmer demand unless that demand is organized around a specific value chain. Value chains have become a dominant framework for orchestrated innovation platforms. Within an AIS, the emphasis on value chains will drive the organization of agricultural research back to a more centralized commodity approach. It will tend to drive the organization of farmer associations along similar lines. Where markets are already well developed, like markets for horticultural exports, organization along commodity lines is already evident. The Fresh Produce Exporters Association of Kenya (see module 1, box 1.5 in the overview) is but one example among many.

INCREASING PRIVATE SECTOR LINKAGES. In general, public agricultural research, especially within a NARI, is organized around core capacities involving some combination of plant breeding, disease and pest management, integrated crop management, soil and water management, livestock and fisheries, and potentially forest and rangeland management. Virtually all of these areas focus on improving land productivity and have farmers as their principal clients, either directly or through bridging organizations such as NGOs, farmer associations, and extension services.

The large change in organizing research within an AIS is the development of linkages between research and an emerging private sector. Research and bridging organizations are not well organized to effect such linkages (Larsen, Kim, and Theus 2009). In small agrarian economies, the private sector is not very prominent in rural areas. Large-scale processing tends to locate in major urban markets. Many nonfarm activities to generate income in rural areas are based in the household, such as brewing beer or processing root crops.³ Haggblade (2009:A1-2) noted that “rural manufacturing remains limited across most of Africa . . . but, overall, local rural services, commercial and other business activity account for 80 percent of rural nonfarm earnings.”

Innovations that have broad impact on the rural nonfarm economy thus tend to focus on organizational innovations that improve marketing efficiency or on small-scale processing where initial market conditions exist to specialize outside the household. The development of technology for small-scale processing relies primarily on mechanical innovations that usually come either from private industry, international borrowing, or occasionally (for specialized processing) from university engineering departments or industrial research institutes (Haggblade, Hazell, and Reardon 2007). The availability of specialized processing equipment depends, however, on the presence of local private capacity for manufacturing and distribution.

What then provides the basis for effective linkages between agricultural research and the private sector in agrarian economies? Strategies include vertical integration, brokering, and public-private partnerships.

In larger-scale processing, such as maize milling or feed production, a company's interest lies in procuring stable supplies of raw material of a certain quality at a competitive price. Where cost structures and margins permit, a company can vertically integrate across the value chain, as in export horticulture. Alternatively it can rely on imports, like the wheat milling industry of coastal West Africa. Under these conditions, there is no incentive for public-private partnerships.

If a company relies on domestic production supplied by market trading, however, it will be interested in combining higher farm productivity and lower costs with more efficient assembly, bulking, and marketing. An agroprocessing firm has little incentive to invest in increased farm-level productivity unless there is a quasi-monopoly on purchases of feedstock, such as for oil palm or sugarcane processing. Innovation platforms for staple food crops tend to focus on linking innovations in assembly and bulking by small-scale marketing agents with technologies for farmers to improve crop productivity. In value chains with significant returns to improved quality (for example, specialized coffee or dairy), coordination is usually needed from the farm to the final processing point. The mechanism for coordinating all of the actors in the value chain is usually provided by a specialized NGO with public funds (in other words, by a brokerage agency). The scope for public-private partnerships in agrarian economies is quite circumscribed, and enhanced farm productivity will generally continue to be the objective of partnerships or platforms.

Another principal sphere of interaction between research institutes and the private sector surrounds agricultural inputs. In this sphere, the potential interactions are more directly complementary. Public research provides varieties for seed companies, can target fertilizer blends and integrate them with organic sources, and can develop integrated pest management packages for safe horticultural production.

In crop breeding, the nature of public-private partnerships changes as competition and product development evolve in the seed market. Evolving private sector capacity in input markets, tied to responsive public research programs, can provide a direct channel for disseminating the products of public research. The public sector can focus its research on areas where input companies do not invest, which tend to be areas with high rates of poverty and ineffective farmer demand.

Technical innovation through AIS approaches

An evolving AIS has an increasing capacity to innovate, and agricultural research plays a key role in technical innovation. Kline and Rosenberg (1986) observed that “contrary to much common wisdom, the initiating step in most innovations is not research, but rather design” (quoted in Sumberg 2005). In this sense, *applied* agricultural research is probably a misnomer, as its central focus is on technology *design*, whether it is the design of an improved variety, an IPM system, a system to manage animal disease, or an agroforestry system. In such instances, the design process focuses to the

extent possible on ensuring that farmers will be able to use the final product, principally to improve farm productivity. Ensuring that technical design is congruent with farmer utilization is a central tenet of farmer participatory research (including participatory plant breeding) and its antecedent, farming systems research, as the design process often entails iterations with farmers in testing and design modification—or rather codesign (see TN 4).

INNOVATION PLATFORMS. In practice, approaches to technical innovation within an AIS often take the form of project-based innovation platforms (TN 1; see also module 1, TN 2). Projects usually operate for a limited time; unsurprisingly they tend to focus on quick solutions to technical problems identified within the platform. This time frame orients research institutions to adapt existing knowledge and technology. Nevertheless, research institutes must balance this increasing demand for capacity to conduct shorter-term adaptive research with the longer-term research capacity required to expand the set of technical options. Farming systems research units were often successful locally but had difficulty achieving any significant scale in the adoption of adaptive research results. A value chain framework, which usually focuses on applied research, expands the specification of the problem and usually integrates technical innovation with institutional innovations in farmer organization and marketing to ensure that results are used throughout the value chain. Yet in many cases it is difficult to scale up results that are specific to particular value chains and contexts, as seen with warehouse receipt systems in underdeveloped grain markets such as those in Sahelian countries.

A research institute can also foster the development of innovation platforms by establishing a specialized unit or through funding arrangements such as those in Latin American research foundations or competitive grant programs. Through these units or funding arrangements, research institutes respond to some form of “articulated” demand, which may come only from a limited proportion of the farming population. Alternatively, the research institute may take a more proactive role and initiate an innovation platform itself, especially if it believes it has a technical innovation with a good chance of success and that an innovation platform is an effective means of ensuring its use. This approach can be described as “linear,” but it is only another form of applying existing knowledge.

SCALE OF INNOVATION PLATFORMS. The scale of innovation platforms has not been much explored (Hall, Dijkman, and

Sulaiman V. 2010). In Africa, innovation platforms often operate at the district level, where the constraints lie in the heterogeneity of production systems and the location in relation to markets. In value chain platforms, scale is determined by the problem, market size, coordination requirements, and structure of the value chain. In Rwanda, for example, the conversion of the coffee subsector to high-value, specialty blends was done at a national, subsectoral level. In comparison, the development of organic horticultural value chains is often organized at the district level or lower. Scale is often a key design criterion in the development of a value chain platform. It determines whether the platform operates at the national, regional, or district level, whether it involves individual versus institutional partnerships, and whether policy change is a key element in the platform's activities.

Platforms that are not structured around value chains and that have poverty or food security objectives tend to approximate rural development programs and rely on public sector or civil society participants. Introducing an innovation perspective into what are essentially facilitation and service delivery platforms requires methodologies that are more participatory, focus more on the problem, and allow greater scope for experimentation. These requirements often limit the scale of operations and introduce higher implementation costs, however. Smaller-scale innovation platforms may be required, which will feed into and support broader rural development programs.

INNOVATION PLATFORMS WITH POVERTY OBJECTIVES. There is a tendency in an AIS to focus primarily on value chain approaches, as for example with the Kenya Agricultural Productivity Program (KAPP). After Kenya liberalized its markets in the 1990s and the private sector became increasingly active, Kenya generated successful market-led approaches to develop smallholder tea, horticulture, and dairy production as well as a fertilizer market. Despite these achievements, rural poverty remains very high in marginal agricultural areas and densely populated areas around Lake Victoria. Most smallholders are still net buyers of maize, the principal staple—only 18 percent of maize producers are net sellers and only 2 percent of producers account for 50 percent of sales (Jayne, Mather, and Mghenyi 2006). The Kenya Agricultural Research Institute, like many small-country agricultural research institutes, faces the dual challenge of innovating through market-led approaches while attempting to expand market participation or minimally improve household food security for the majority of smallholders.

As discussed, in India, NAIP (IAP 2) has managed the trade-off between market-driven innovation and innovation for lagging areas by creating two funding streams to support different types of innovation clusters. In lagging areas, funding supports the transaction costs involved in establishing innovation platforms and organizing partnerships. These platforms are bound by the duration of the grant, however, and either the problem focus has a short-term horizon, the results can be seen as a pilot for which larger-scale funding would be sought, or the funding is structured so that follow-up grants would be awarded to promising longer-term problem areas. However, a NARI such as the one in Kenya must internalize these trade-offs within the frame of its own research programming, the number of partnerships it can manage, the duration of the partnerships, and in the end the public good objectives that drive these decisions. In other words, it must prioritize whether to invest in more scientific capacity or collaborative capacity.

TAKING NOTE OF LONG-TERM NEEDS. Planning for longer-term needs in regard to technical innovation tends to take place in well-developed market economies and tends to focus on capacity needs in relation to basic and strategic research. At this stage in the development of the agricultural economy, there is a strong sense that new science will be a principal engine of continued agricultural growth and competitiveness in world markets. Scenario planning is often used to gauge alternative futures in relation to the evolving structure of the agricultural economy and to chart longer-term investment needs in agricultural R&D.

In developing countries, the private sector does not invest in scenario planning, although multinationals such as Monsanto do use such approaches, and a clearer division of labor emerges between public and private R&D. In developing basic research consortiums, NAIP used foresight scenario planning (see module 7, TN 3) to define longer-term needs. Tapping the potential of genomics and molecular biology as well as the potential of bioenergy often becomes a key focus in supporting continuing structural change in the overall economy.

KEY POLICY ISSUES

The key policy issues surrounding agricultural research in an innovation system range from the very broad (the need for an environment conducive to organizational interaction) to the very specific (the need for particular policy instruments that reduce the transaction costs of organizational

collaboration). Policies that promote decentralization and democratization can also have a positive effect on rural innovation.

Incentives for organizational interaction

Within AISs, framework policies provide the broad incentives for increased organizational interaction in support of agricultural innovation: market policies, administrative policies, and financing mechanisms. Policies in general should enhance collaboration, collective action, and what might be termed “functional sufficiency” in innovation—the participation of a diversity of actors that bring a sufficient set of skills to the innovation process. As noted, market liberalization policies have been a critical driver of investments in the agricultural sector, market participation, and growth linkages in the rural economy.

With the trend toward market liberalization, government’s role has shifted to improving marketing efficiency and defining standards for market participation, particularly the development of grades and standards in commodity markets and quality and safety standards in input markets. Seed certification, varietal testing and release, biosafety regulation, plant breeders’ rights, and IPRs (see module 6) all set the rules under which product innovation takes place. They define the rules of competition (for example, between seed companies) and provide incentives for collaboration (for example, between integrated pest management firms and horticultural producers). The regulatory environment in turn provides incentives for the private sector to increase its investment in research, which often initially provokes competition with public research and then evolves into more collaborative modalities. The tension then becomes whether public research, especially if jointly funded by the public and private sector, is done under exclusive rights to particular companies or whether the research supports the whole agricultural sector. In general, public research turns its attention to more upstream research that has longer time horizons and addresses issues of less importance to the private sector, such as natural resource management, poverty reduction, gender, and equity.

Financing for transaction costs inherent in AISs

Financing mechanisms are possibly the most effective policy instruments for increasing organizational connectivity (box 4.1). Aside from providing incentives, financing mechanisms are also critical for supporting the increased

transaction costs inherent in developing organizational linkages and platforms. Where benefits to collaboration are clear, particularly for the private sector, such transaction costs are a necessary component of investments in the innovation process. For public sector research, however, financing these costs requires explicit budgeting categories and clarity on how these expenditures will support institutional outcomes. To overcome the inherent risk and uncertainty and cover transaction costs for participation, special agricultural innovation funds (module 5, TN 2) have been developed (World Bank 2010).

Decentralization and equity issues

The trend toward democratization is often reflected in greater administrative and financial decentralization, in which the delivery of public services is managed at the district level and the public agencies involved become more accountable to local constituents, including women and men farmers. Decentralization has had a major impact on the organization of advisory services, animal and plant health services, and the development of infrastructure, especially for water and rural roads. Democratization is also accompanied by an expansion in civil society organizations, including the rebuilding of farmer organizations. In many respects, these processes are fundamental to creating capacity for rural innovation. In areas where local government is particularly responsive, they can facilitate innovations such as the Land Care movement in the Philippines.

EVOLVING AREAS OF INVESTMENT IN RESEARCH WITHIN AN AIS

How will research investments continue to evolve in an AIS context? Investments are expected to continue supporting the wider connections that lead to innovation. They will encompass new forms of collaboration and institutional structures as well as new technologies and systems that increase the flow of information among actors in an innovation system.

In some instances, greater collaboration and communication between actors in an innovation system will change where agricultural research occurs, who conducts and funds it, and its priorities. In Africa, however, public research agencies will be even more challenged to respond to the proliferation of small-scale innovation processes. Research investments will also be critical for counterbalancing the heavy market orientation of AISs and promoting greater inclusiveness and equity in innovation processes.

Box 4.1 Financing Agricultural Research and Innovation

Agricultural research in developing countries is characterized by significant underinvestment, especially in Africa. It remains very much a public activity that produces public goods. Government remains the largest contributor to public agricultural research, accounting for an average of 81 percent of funding. Internally generated funds, including contracts with private and public enterprises, account for only 7 percent. Because continuity of financing is so critical to the productivity of agricultural research, new approaches to funding have been piloted over the past two decades. As the precursors of funding strategies for AISs, they offer insight into the potential challenges involved.

The new approaches shared two fundamental characteristics. They separated funding decisions from the execution of research and they expanded the sources and sustainability of financing.

To ensure accountability and a research agenda that met users' needs, representatives of the private sector, farmers, and the public sector decided which research to fund, primarily through competitive grants. This separation required new organizational arrangements to manage the increased transaction costs, most often in the form of a research foundation, a national agricultural research council, or a government agency that managed competitive grants (see module 6, TN 2). Experience with research foundations yielded lessons on ensuring clients had a voice in funding decisions and on developing sufficient capacity to manage the funding within a strategic framework.

Research foundations and competitive grant funds have focused on funding projects that foster critical partnerships in the AIS, usually between public scientific institutes and the private sector. For example, Chile

organized clusters in which firms' market, processing, and management expertise were matched with expertise from public research institutes (IAP 3). Three government agencies, each with a slightly different mandate, managed the funding. In India a similar program was managed by a program office organized within a World Bank loan (IAP 2). The primary funding mechanism was competitive grants, awarded to specific types of partnerships, often with explicit contractual terms.

To diversify and sustain funding, the beneficiaries of the research are increasingly required to contribute. In Kenya, for example, levies have funded research on export crops (tea and coffee). In Uruguay, producer associations invested directly in national commodity research programs. More generally, tax incentives have encouraged companies to invest in R&D by hiring their own researchers or contracting with public agencies. In all of these arrangements, the research supported is defined much more specifically to reflect users' demands, ensure that appropriate products are developed, and promote accountability.

Such funding sources are still a small component of overall funding for agricultural research, however. Large parts of the agricultural sector still rely almost entirely on public funds to meet their needs, especially for plant breeding research in staple food crops and natural resource management research.

The *key lesson* is that a strong market and commercial orientation, if not bias, appears to exist in financing arrangements that move away from financing research and toward financing innovation within an AIS. A primary challenge is to ensure that research and innovation to generate public goods will be adequately supported.

Sources: Agricultural Science and Technology Indicators (<http://www.asti.cgiar.org>); Byrnes and Corning 1993.

Increasing connectivity between research and other innovation actors

In an AIS, research is chiefly oriented toward integration with the rest of the innovation actors, be they private, public, or civil society entities. In practice, most efforts have focused on interactions between the public and private sectors. Partnerships between public and private agencies involve a range of contractual arrangements, from informal to formal, under which research institutes provide products

or services to the private sector. For a public research agency, the degree of exclusivity in the use of its particular product or service, which is often under IP protection, often defines the contractual arrangement (see TN 2 in this module and module 5, TN 1).

Science parks create a useful nexus between commercial enterprises and research institutes by taking promising research products to market and providing backstopping in product modification. They function best where private

investment capital and industrial engineering expertise coexist (see the overview in module 5).

The development of new markets for agricultural products often calls upon public expertise in agronomic and breeding research and relies on services ranging from brokering contracts and partnerships and assembling investment capital to developing capacity in the private sector. The costs of research for these niche markets often cannot be justified for public research institutes with their broad public good mandates. This issue is explored further in module 3, TN 4.

Value chain platforms, the most informal approach to linking publicly funded research and the private sector, seem to function best when coordination is needed to produce a specialized product like high-quality coffee. They require external funding and facilitation, and their effectiveness in generating innovation for a range of commodities and market conditions remains to be tested (see module 1, TN 2 and module 5, TN 4).

Enhancing access to information and communication

Enhanced information flows will improve the integration of an AIS. The facilitating role of ICTs is vital for researchers and other stakeholders in an AIS involved in gathering and manipulating data or interacting with global information resources (see box 4.2) (see World Bank 2011).⁴ Information flows among actors in an AIS in developing countries have always been particularly costly, often asymmetric, and generally incomplete. New ICTs could significantly improve access to information and the availability of communication and collaboration tools, although access to information is only one component of the innovation process in agricultural systems. The design of technology in agricultural research oriented to increased farm productivity depends on a two-way flow of information between farmers and researchers. Farm-level innovation requires contextualized information (a particularly difficult problem, especially where farmers' level of education is limited), access to research products, and a significant learning-by-doing process. Researchers in turn need to understand the heterogeneity of farming systems and the constraints on farm productivity to inform their technology design and testing systems and ensure that they respond to farmers' needs. Some emerging areas of investment are discussed in the sections that follow.

MOBILE PHONES AS AN INFORMATION EXCHANGE DEVICE. Mobile phones are becoming pervasive in some rural areas.

Box 4.2 ICTs Make Agricultural Research More Inclusive

ICTs are making agricultural research more inclusive and at the same time more focused on development goals, because they change how, where, and to whom information flows. Information can flow in many directions; it can be highly dispersed and accessible; it can also be highly targeted and location specific. ICTs are significant in the research process but may be even more significant as a catalyst throughout the wider innovation system, in: collecting, storing, and analyzing data, with or without human interaction; geospatial applications; decision support and knowledge-based systems and robotics; embedded ICTs in farm equipment and processes (agronics); connecting communities and enabling learning; collaboration with stakeholders across the research process; and the management of competitive innovation funds.

Sources: Agricultural Science and Technology Indicators (<http://www.asti.cgiar.org>); Byrnes and Corning 1993.

They are more than a mechanism for two-way flows of information. Kenyan farmers use them to obtain market prices, verify the certification of seed and fertilizer sellers, and obtain recommendations on which fertilizer and seed to choose. Equipped with GPS and cameras, mobile phones are becoming a very efficient means for researchers and farmers to collect farm-level information. For example, a network of sentinel farmers in the Great Lakes region of Africa monitors two cassava disease pandemics, the hybridized form of cassava mosaic virus and two species of cassava brown streak virus. A data template has been developed with the service provider, and farmers provide photographs of suspected new outbreaks. This effort could evolve into an interactive disease surveillance and control system. The potential of mobile phones for such interactive information flows between researchers and farmers will continue to evolve.

MARKET INTELLIGENCE UNITS. Within an AIS, research institutes will increasingly have to balance farmers' demands with those of the private sector, which will affect farmers indirectly through research that produces innovation elsewhere in the value chain. Within commercial agricultural economies, information flows are increasingly

specific to the needs of each subsector. Market intelligence becomes an important public good in improving the efficiency of the market and directing investment in the subsector, including research investment. In countries such as Brazil, the Brazilian Institute of Geography and Statistics collects basic census and production data,⁴ while agricultural economic research institutes collect information on prices, domestic trade volumes, agroprocessing output, and international markets and undertake analytical work in support of market development.

LEARNING ALLIANCES. Learning alliances provide a platform for networking often disparate R&D institutions around a common focal area involving program or project development and implementation. They focus especially on the learning associated with scaling up innovations, which usually involves the interaction of research, capacity building, project implementation, and evaluation. These platforms move beyond the scope of a traditional monitoring and evaluation (M&E) system and focus on broader learning objectives across institutions. Learning alliances are particularly intensive in the use of facilitation and information synthesis and require external funding to operate. See IAP 4.

Organizational change of research within an evolving AIS

Organizational change within a research system reflects increasing differentiation and specialization in the production of new knowledge, products, and services. This differentiation among R&D organizations is driven by improvements in their ability to respond to changing demands within the agricultural sector as organizational linkages within the sector improve (TNs 1 and 5; box 4.3). Closer interaction between publicly funded agricultural research and an expanding private sector and civil society has organizational implications for research because interaction shifts the locus of agricultural research, research priorities, and research financing.

This shift is most apparent in the rapidly growing economies of Asia, which are experiencing increasingly dynamic organizational change. Private investment in agricultural research is expanding rapidly, especially in plant breeding. Hybrid maize led the movement of seed companies into breeding, but they have since expanded into horticulture, hybrid rice, and plantation crops. In Asia and Latin America, public plant breeding has responded to these developments by either moving toward more prebreeding

and genomics research in support of the private sector or toward breeding for areas not covered by the private sector (box 4.4).

In sub-Saharan Africa the market and agricultural research context remains quite different, requiring NARIs to balance traditional research focusing on productivity with an emergent private sector that has almost no capacity to undertake research. Finding this balance, improving connectivity to the private sector to improve farmers' access to markets, and developing more effective linkages to bridging organizations that provide services to farmers are all on the agenda of how the NARI improves its connectivity within the AIS.

In many cases, approaches will vary depending on location and commodity, as research organizations have a role even in postconflict situations. In all cases, enhanced partnerships with a diversity of NGOs, farmer organizations, and civil society organizations are critical to effective performance.

With their persistent funding constraints, African NARIs face an increasing dilemma in organizing themselves to respond to an expanding range of innovation processes, which are often grouped around relatively micro market and development niches. As Hall, Dijkman, and Sulaiman V. (2010: 4) have argued, "Innovation diversity is central to research design, emphasizing that there is no optimal approach or way of organizing research into use for innovation and impact; rather it is context-specific and path-dependent." How African NARIs address the diversity question in their external linkages while organizing their limited internal resources around the biotic, natural resource, and impending climate change challenges facing African agriculture will be a persistent driver of organizational change within NARIs. Such change is best built on experimentation, piloting, and continuing enhancement of skills in developing external institutional arrangements, while evolving increased flexibility in designing research products and services.

Pro-poor innovation

The market orientation of AIS raises a number of challenges with respect to pro-poor innovation; in many ways these challenges echo the debate over the equity impacts of the Green Revolution. First, the rural poor are primarily found in contexts characterized by poorly developed markets, either because of inadequate transport infrastructure, distance to markets, or low population density. The poor often reside in marginal areas bypassed by private investment

Box 4.3 The Consultative Group on International Agricultural Research and the AIS

The institutional role of the 15 centers of the Consultative Group on International Agricultural Research (CGIAR) in agricultural innovation has been a source of debate and has changed significantly over time. The issue is most often framed in terms of where the centers operate within the research-to-development spectrum.

- For the first two to three decades, the centers' role was defined in terms of a division of labor with the NARIs (the centers would mostly develop technologies and NARIs would refine and disseminate them). Significant investment in training and capacity building within NARI research programs were made to develop a technology pipeline.
- Farming systems and participatory research in the 1980s and 1990s expanded the institutional matrix within which the centers operated (and the number of centers themselves expanded). The focus shifted from pushing the supply of technology to understanding farmers' demand for research and conducting more work on natural resource management. Core funding shifted to competition for project funding. The shift heightened the emphasis on achieving development outcomes—but within a less strategic, more project-driven modality.
- The 2000s saw Centers consolidate their downstream research and focus methodological develop-

ment under frameworks such as integrated natural resource management, agricultural research for development (AR4D), and knowledge to action programs—all forerunners or embodiments of AIS. Demand articulation was embedded in each of these approaches, and organizational and institutional innovation were seen as critical complements to technical innovation. The institutional matrix within which the centers worked expanded again.

In its current incarnation, the CGIAR intends for its 15 centers to function more as a system than as autonomous centers. They will operate through multi-center CGIAR Research Programs (CRPs). Financing will return to longer-term core funding allocated by funders through a Fund Council that is legally separate from the centers; centers will be governed by a Consortium Board. CRPs will be managed within a results-oriented framework and evaluated with respect to their contributions to four system-level outcomes. The new arrangements incorporate elements of an AIS approach, with a focus on measurable results (which are reflected in the contractual arrangements between each CRP and the Fund Council). This results orientation will have to differentiate between innovation-induced rural change and structured implementation of development projects.

Source: Author.

Box 4.4 Examples of Public-Private Engagement in Prebreeding and Genomics

Thailand has invested in higher-end genomics research and molecular breeding, not in the Ministry of Agriculture and Cooperatives but rather in the Ministry of Science and Technology. This high-end science is organized in clusters with private companies.

In Indonesia and the Philippines, the private sector accounts for one-fifth of agricultural R&D, partly because of the plantation structure of significant parts of the agricultural economy. In turn, the Indonesian Research Institute for Estate Crops generates a significant portion of its budget from contract research and commercial seed sales.

Source: Beintema and Stads 2008.

The same trends are apparent in Latin America, although not to the degree of Indonesia and Philippines. Colombia, Uruguay, and Argentina fund research on coffee, rice, sugar, and oil palm from levies on commodity sales. Chile has a number of specific competitive funds, all of which require collaboration with industry. These trends suggest that agricultural research is moving away from direct involvement with farmers and that private companies are increasingly the intermediaries between researchers and farmers.

until rural wages start to increase dramatically in other areas. The potential for developing sustainable links to markets under such circumstances is often limited.

Second, where market development is possible, the rural poor often lack the resources to access markets. Ensuring the participation of women is even more challenging. Women's roles in the value chain and the services that support those roles may need to be differentiated. Organizational innovations may also be needed to ensure that women participate in and benefit from the formation of farmer groups.

Finally, agricultural research linked to development agencies often has a significant role in improving food security for more subsistence-oriented households, including food-based nutritional approaches (especially for households affected by AIDS), limiting the "hungry season," and improving the resilience of the farming system. An AIS framework requires a very different institutional mix and methodologies to support innovation in such contexts, potentially extending into learning alliances. For AIS approaches, the incentives for researchers tend to come from more commercial producers, especially when researchers are working with value chains. A pro-poor innovation process requires more orchestrated investment approaches and in the end much more experience and evaluation of how the innovation process can be sure to include the poor.

MONITORING, EVALUATION, AND SCALING UP

Monitoring the performance of agricultural research within an agricultural innovation framework presents a number of conceptual and implementation issues. Optimally an M&E system will function at a project level, at a research institute and research system level, and at the level of the overall AIS, and indicators developed at lower levels will aggregate to higher levels. Virtually all of the experience with M&E in innovation systems is at the project level, however.

Spielman and Kelemework (2009) have developed an AIS performance index and tested it in Ethiopia and Vietnam. They divided the AIS into organizational domains, one of which was the knowledge and education domain, which includes agricultural research. Performance in this domain was measured in terms of knowledge production, reflected primarily in scientific publications.

When innovation outcomes are defined at the level of the overall AIS, the performance measure for agricultural research shifts from farmers' adoption of technology to the role of agricultural research as a producer of knowledge.

Impact at the farm level is attributed to the AIS rather than the agricultural research institutes. In the overall AIS, the monitoring of agricultural research organizations shifts toward process-oriented assessment (Daane 2010), the characterization of systemic linkages between agricultural research and other domains within an AIS, and their functionality. Ragasa et al. (2010) used this approach in developing an M&E system for agricultural research in Nigeria.

At the project level in an AIS, M&E in many ways is more comprehensive and tends to be organized around value chains, innovation platforms, public-private partnership arrangements, or competitive grants. In such contexts, agricultural research will be only one of many organizational partners in the M&E framework. The focus will be on understanding and adapting processes, often within an action-research modality (an iterative process of diagnosis, planning, action, evaluation, and reflection). The M&E system will serve several functions, particularly (1) monitoring project progress; (2) learning and change; (3) collecting data for testing hypotheses, often in relation to scaling up project results; and (4) project management (Njuki et al. 2010). Data will be collected on a combination of quantitative and qualitative indicators, the latter often collected through a participatory M&E process with project participants.

Defining the scope of innovation outcomes is often not straightforward. The outcomes reflect the application of new knowledge, products, or services within a context of organizational or institutional innovations. Investors will want to know the impact of these innovation outcomes and whether the organizational innovations are more cost effective than current institutional arrangements.

In a few cases, as in the sub-Saharan Africa Challenge Program of the CGIAR, experimental and quasi-experimental methods have been employed to test the comparable efficiency gains from using innovation system methods over traditional research and extension approaches (FARA 2009). Such tests are very expensive, however, and in the end not as rich as adaptive approaches employing M&E data in progressively improving the efficiency of AIS methods and processes.

Table 4.1 provides selected indicators for topics covered in this module.

ORGANIZATION OF THIS MODULE

Agricultural research within an AIS framework is still in quite early stages of development, and the experiences and applications described here have been drawn from a number of contexts and often within a piloting modality. This material has

Table 4.1 Schematic of a Monitoring and Evaluation Framework for Assessing the Performance of Agricultural Research within an AIS

Domain	Indicator
Innovation outcomes/research impact	<ul style="list-style-type: none"> – Technology adoption – Increased farm productivity and incomes – Increased efficiency within the value chain – Increased total factor productivity – Increased agricultural GDP
Demand articulation	<ul style="list-style-type: none"> – Forums for farmer voice – Joint priority setting – Participatory or codesign research – Number of public-private partnerships (PPPs)
Organizational interfaces/partnerships	<ul style="list-style-type: none"> – Number of innovation platforms, clusters, or consortiums – Number of PPPs – Value chain platforms – Scientist participation in networks
Organizational change	<ul style="list-style-type: none"> – Involvement of stakeholders in planning, priority setting, and evaluation – Presence of mechanisms or units for managing partnerships and for brokering innovation processes
Research productivity	<ul style="list-style-type: none"> – Number of competitive grants received – Number of peer reviewed articles published – Number of varieties released – Number of on-farm trials
Knowledge flows	<ul style="list-style-type: none"> – Number of hits on website – Articles or programs in mass media – Citation index – Extension bulletins produced and distributed

Source: Author.

Note: All indicators should be disaggregated by gender when possible.

been organized by typology in this overview and by theme in the notes that follow (except for TN 1).

The typology emphasizes that the market, organizational, and economic context needs to be understood in deciding on investment approaches for AIS. The themes covered in the notes enter into more detail on alternative areas of investment in important domains of AIS. They include a discussion of demand articulation and external organizational interfaces (TN 1); public-private partnerships (TN 2), regional research (TN 3), codesign in agricul-

tural research (TN4), and management structures and organizational change (TN 5).

The TNs are followed by profiles of innovative approaches to agricultural research within an AIS framework. IAP 1 discusses the redesign of an international agricultural research center to align with an AIS approach. Two profiles focus on the implementation of agricultural innovation funds, especially in facilitating public-private partnerships, in India and Chile (IAPs 2 and 3). Another describes experiences with learning alliances (IAP 4)