Agricultural Innovation Systems
AN INVESTMENT SOURCEBOOK
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THE WORLD BANK
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Agricultural development depends on innovation. Innovation is a major source of improved productivity, competitiveness, and economic growth throughout advanced and emerging economies, and plays an important role in creating jobs, generating income, alleviating poverty, and driving social development.

If farmers, agribusinesses, and even nations are to cope, compete, and thrive in the midst of changes in agriculture and economy, they must innovate continuously.

Investments in science and technology are a key component of most strategies to improve and maintain agricultural productivity and innovate.

Research, education, and extension investments are necessary components but have not been sufficient for agricultural innovation to occur. Other conditions and complementary interventions are needed.

In addition to a strong capacity in R&D, components of effective agricultural innovation are collective action and coordination, the exchange of knowledge among diverse actors, the skills, incentives and resources available to form partnerships and develop businesses, and enabling conditions that make it possible for actors to innovate. These conditions and complementary interventions have not been consistently addressed to date.

Innovation and business development by different stakeholders does not occur without complementary investments to create a supportive environment. Enabling conditions in a given context depend on a (innovation) policy mix, innovation governance, a diverse set of regulatory matters and other investments with synergistic effects.

The agricultural innovation system (AIS) investments must be context specific and respond to the stage of and vision for development in a particular country and agricultural sector. Given the resource limitations, investments need to be assessed, prioritized, sequenced, and tailored to the needs, challenges, and resources that are present.
Consensus is developing about what is meant by “innovation” and “innovation system” (box 1). The agricultural innovation system (AIS) approach has evolved from a concept into an entire subdiscipline, with principles of analysis and action, yet no detailed blueprint exists for making agricultural innovation happen at a given time, in a given place, for a given result. This sourcebook draws on the emerging principles of AIS analysis and action to help identify, design, and implement the investments, approaches, and complementary interventions that appear most likely to strengthen innovation system and promote agricultural innovation and equitable growth.

Although the sourcebook discusses why investments in AISs are becoming so important, it gives most of its attention to how specific approaches and practices can foster innovation in a range of contexts. Operationalizing an AIS approach requires a significant effort to collect and synthesize the diverse experiences in AISs. The information in this sourcebook derives from approaches that have been tested at different scales in different contexts. It emphasizes the lessons learned, benefits and impacts, implementation issues, and prospects for replicating or expanding successful practices. This information reflects the experiences and evolving understanding of numerous individuals and organizations concerned with agricultural innovation, including the World Bank. (For a complete list of the contributors, see the Acknowledgements.)

The sourcebook is targeted to the key operational staff in international and regional development agencies and national governments who design and implement lending projects and to the practitioners who design thematic programs and technical assistance packages. The sourcebook is also an important resource for the research community and NGOs and may be a useful reference for the private sector, farmer organizations, and individuals with an interest in agricultural innovation.

This overview begins with a discussion of why innovation is vital to agricultural development, how innovation occurs, and why complementary investments are needed to develop the capacity and enabling environment for agricultural innovation. It concludes with details on the sourcebook’s structure, a summary of the themes covered in each module, and a discussion of the cross-cutting themes treated throughout the sourcebook.
INNOVATION AND AGRICULTURAL DEVELOPMENT

Agricultural development enables agriculture and people to adapt rapidly when challenges occur and to respond readily when opportunities arise—as they inevitably will, because agriculture’s physical, social, and economic environment changes continually (box 2). Some changes occur with unpredictable force and suddenness; since June 2010, for example, rapidly rising food prices have pushed about 44 million people into poverty, and another 10 percent rise in the food price index could impoverish 10 million more people. Food prices are expected to remain volatile for the foreseeable future. Other changes emerge more gradually but are no less significant. Agriculture is more vulnerable to the increasing effects of climate change than any other economic sector, and it uses almost 80 percent of the world’s freshwater—a vanishing resource in some parts of the world. A changing, less predictable, and more variable environment makes it imperative for the world’s farmers and fishers to adapt and experiment. They require more knowledge that contributes to sustainable, “green” growth—as well as a greater capacity to help develop such knowledge.

Like climatic variability, globalizing markets for agricultural products, far-reaching developments in technology, and equally transformative evolution in institutions (including new roles for the state, the private sector, and civil society) have also been altering agriculture’s social and economic landscape over the past few decades (World Bank 2007b). Agriculture increasingly occurs in a context where private entrepreneurs coordinate extensive value chains linking producers to consumers, sometimes across vast distances. A growing number of entrepreneurial smallholders are organizing to enter these value chains, but others struggle with the economic marginalization that comes from being excluded from such opportunities.

In this context, markets, urbanization, globalization, and a changing environment not only influence patterns of consumption, competition, and trade but drive agricultural development and innovation far more than before. More providers of knowledge are on the scene, particularly from the private sector and civil society, and they interact in new ways to generate ideas or develop responses to changing agricultural conditions (World Bank 2006).

If farmers, agribusinesses, and even nations are to cope, compete, and thrive in the midst of changes of this magnitude, they must innovate continuously. Investments in public research and development (R&D), extension, education, and their links with one another have elicited high returns and pro-poor growth (World Bank 2007b), but these investments alone will not elicit innovation at the pace or on the scale required by the intensifying and proliferating challenges confronting agriculture.

HOW AGRICULTURAL INNOVATION OCCURS

Agricultural innovation typically arises through dynamic interaction among the multitude of actors involved in growing, processing, packaging, distributing, and consuming or

Box 2: The World’s Need for Agriculture, Agricultural Development, and Innovation

In one way or another, agriculture is integral to the physical and economic survival of every human being. The United Nations forecasts that the global population will reach more than nine billion by 2050. To feed everyone, food production will have to increase by 70 percent. Helping the world’s farmers and fishers to achieve this target is challenging in itself, but beyond providing food, agriculture sustains the economies of most countries in significant ways, especially in the developing world. Across sub-Saharan Africa, for example, agriculture accounts for three-quarters of employment and one-third of GDP. Seventy-five percent of the world’s poor live in rural areas and have an economic link to agriculture. For very poor households, agricultural development is not only a defense against hunger; it can raise incomes nearly four times more effectively than growth in any other sector. These circumstances help to explain why agricultural development is such a powerful tool for reducing global poverty and eliciting economic development.

Agricultural development demands and depends on innovation and innovation systems. Innovation is widely recognized as a major source of improved productivity, competitiveness, and economic growth throughout advanced and emerging economies. Innovation also plays an important role in creating jobs, generating income, alleviating poverty, and driving social development.

Source: Authors and OECD 2009.

Photo: Jianchu Xu, World Agroforestry Centre.
otherwise using agricultural products. These actors represent quite disparate perspectives and skills, such as metrology, safety standards, molecular genetics, intellectual property, food chemistry, resource economics, logistics, slash-and-burn farming, land rights—the list is far too long to complete here.

For innovation to occur, interactions among these diverse stakeholders need to be open and to draw upon the most appropriate available knowledge. In addition to a strong capacity in R&D, components of effective agricultural innovation are collective action and coordination, the exchange of knowledge among diverse actors, the skills, incentives and resources available to form partnerships and develop businesses, and enabling conditions that make it possible for actors to innovate.1 Box 3 provides examples of how innovation has occurred in agriculture.

**Agricultural Innovation Systems**

Research, education, and extension are usually necessary but not sufficient to bring knowledge, technologies, and services to farmers and entrepreneurs to innovate. Innovation requires a much more interactive, dynamic, and ultimately flexible process in which the actors deal simultaneously with many conditions and complementary activities that go beyond the traditional domains of R&D and extension. These conditions and complementary interventions have not been consistently addressed to date; new, additional ways and means of doing so are needed.

An AIS approach looks at the multiple conditions and relationships that promote innovation in agriculture. It may offer a more flexible means of dealing with the varied conditions and contexts in which innovation must occur. It considers the diverse actors involved, their potential interactions, the role of informal practices in promoting innovation, and the agricultural policy context.

The AIS principles of analysis and action integrate the more traditional interventions (support to research, extension and education and creating links between research, extension, and farmers) with the other complementary interventions needed for innovation to take place. Such in-

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**Box 3: Examples of Agricultural Innovation and Innovation Processes**

The instances of agricultural innovation listed here came about in different ways. In some cases, markets heightened the pressure to innovate, and the private sector played a decisive role in driving the subsequent innovation. In others, public sector interventions, such as policy, R&D, and other incentives, drove the innovation process.

- **Cassava processing innovation system, Ghana.** Research-led development and promotion of new cassava products with a private sector coalition.
- **Cut flower innovation system, Colombia.** Continuous innovation in response to changing markets, using licensed foreign technology and coordinated by an industry association.
- **Medicinal plants innovation system, India.** Mobilizing traditional and scientific knowledge for rural communities, coordinated by a foundation.
- **Small-scale irrigation innovation system, Bangladesh.** Civil society organization promoted low-cost pump to create markets. Small-scale manufacturers then innovated with pump designs in response to local needs.
- **Golden rice innovation system, global.** Complex partnership of multinational companies, international agricultural research organizations, universities, and development foundations. Complex but creative institutional arrangements over ownership. Innovation targeted to poor (nutrient-deficient) users.
- **Potato, Peru.** International research center facilitated development of new indigenous potato products with a coalition of researchers, smallholders, and multiple private actors (including supermarkets, traders, and restaurants).

In each case, the drivers for innovation and growth were different and the role of research and extension varied, but in all cases the actors used similar approaches to address their respective challenges and innovate. The challenges included meeting stringent quality standards, remaining competitive, responding to changing consumer tastes, and addressing technological problems.

The actors’ ability to improve their interactions and strengthen their links to one another proved crucial to their success. All of the cases illustrate the importance of collective action, facilitation and coordination by intermediaries, building a strong skill base, and creating an enabling environment for innovation to take place.

*Source: Bernet, Thiele, and Zschocke (2006); Hall, Clark, and Naik (2007); World Bank (2006); A. Hall and R. Rajalahti (personal communication).*
Interventions include providing the professional skills, incentives, and resources to develop partnerships and businesses; improving knowledge flows; and ensuring that the conditions that enable actors to innovate are in place.

Figure 1 presents a simplified conceptual framework for an AIS. The figure shows the main actors (typical agricultural knowledge and technology providers and users, as well as the bridging/intermediary institutions that facilitate their interaction); the potential interactions between actors; and the agricultural policies and informal institutions, attitudes, and practices that either support or hinder the process of innovation.

**EFFECTS TO STRENGTHEN KEY COMPONENTS OF THE INNOVATION SYSTEM**

Agricultural research, extension, education, and training are key components of an AIS. The following sections summarize approaches that have been used to strengthen these components, what they achieved, and continuing concerns.

**Agricultural Research**

A strong science and technology system—encompassing basic, strategic, and adaptive agricultural science as well as sciences outside agriculture—is widely regarded as contributing to innovation and sustainable, equitable agricultural development. Development cannot occur without knowledge, much of which must be generated and applied nationally and often more locally. For this reason, sustaining food production and rural livelihoods while reducing poverty depends to a great extent on how successfully knowledge is generated and applied in agriculture and on whether the capacity to produce such knowledge is improved.

Aside from budgetary constraints (box 4), many public research organizations face serious institutional constraints that inhibit their effectiveness, constrain their ability to attract funds, and ultimately prevent them from functioning as a major contributor to the innovation system. The main constraints associated with many national research organizations result from strong path-dependency in institutional development and slow institutional and policy change, such...
as the lack of consensus on a strategic vision, ineffective leadership and management, a continued emphasis on building centralized national agricultural research structures rather than creating partnerships, the loss of highly qualified scientific staff, and weak links with and accountability to other actors involved in innovation processes (World Bank 2005).

Over the years, research organizations have attempted to address these various constraints. Most of these efforts have centered on shifting investments away from physical infrastructure, equipment, human resource development, and operating funds and toward improvements in the management of public research organizations—for example, through better planning, improved financial management, greater accountability, and more relevant programs for clients (developed with oversight from multistakeholder boards or through better research-extension linkages).

Much effort has focused on increasing client participation and on the financing and overall development of pluralistic agricultural knowledge and information systems (World Bank 2005). Table 1 captures the main differences and changes in emphasis in World Bank investments to support innovation. Box 5 describes recent reforms in agricultural research and extension organizations.

Approaches to international cooperation in agricultural R&D continue to change as well. Growing capacities in large national agricultural systems such as those of Brazil, China, India, and South Africa hold huge potential for increased South-South cooperation, especially given the number of smaller developing countries that lag behind these agricultural research giants. These realities, among others, have impelled the Consultative Group on International Agricultural Research (CGIAR)—a global partnership of organizations that fund and conduct research for sustainable agricultural development—to examine and revise its approach to agricultural R&D through a change management process initiated in 2008.

Besides giving high priority to effectiveness, accountability, cost-effectiveness, and staff quality, research supported by the CGIAR will be based on the development of results-oriented research agendas directed toward significant and compelling challenges. The CGIAR will give particular
attention to enabling effective partnerships, because the complexity of scientific advances, socioeconomic developments, and environmental impacts, along with the higher costs associated with new lines of research, make partnerships essential for producing and delivering international public goods in agriculture. The CGIAR’s contribution to

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<th>National agricultural research systems</th>
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<th>Agricultural innovation systems</th>
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<tr>
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<td>Farmer, research, extension, and education</td>
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<td>Strengthening infrastructure and human resources</td>
<td>Strengthening communication between actors in rural areas</td>
<td>Strengthening interactions between all actors; creating an enabling environment</td>
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**Table 1: Defining Features of the Three Main Frameworks Used to Promote and Invest in Knowledge in the Agricultural Sector**


Box 5: Recent Reforms in Public Agricultural Research and Extension

- Increasing the participation of farmers, the private sector, and other stakeholders in research governing boards and advisory panels to attain real influence over research decisions and priorities. The participation of women farmers is particularly important, given their crucial role in rural production systems, the special constraints under which they operate (for example, time constraints), and their range of activities and enterprises, including marketing, processing, and food storage.
- Decentralizing research to bring scientists closer to clients and better focus research on local problems and opportunities.
- Decentralizing extension services to improve accountability to local users and facilitate clients’ “purchase” of research services and products that respond better to their needs. Matching grant programs for farmer and community groups allow them to test and disseminate new technologies.
- Establishing competitive funding mechanisms that involve key stakeholders, especially users, in promoting demand-driven research, setting priorities, formulating projects, and screening proposals. Competitive funds have increased the role of universities in agricultural R&D in some countries. Continuing challenges include limited engagement with the private sector, sustainability of funding, the bias against strategic R&D, and the heavy transaction costs.
- Promoting producer organizations to reach economies of scale in services and market activities, increase farmers’ ability to demand better services, and help producers hold service providers accountable.
- Mixing public and private systems by enabling farmer organizations, nongovernmental organizations (NGOs), and public agencies to outsource advisory services, identify the “best fit” for the particular job, and recognize the private-good attributes of some extension services. For example, approaches based on public funding that involve local governments, the private sector, NGOs, and producer organizations in extension delivery may be most relevant to subsistence farmers, whereas various forms of private cofinancing are appropriate for commercial agriculture, extending to full privatization for some services.

agricultural development through research and knowledge management must be integrated with the wider development goals and activities of other actors, notably countries, international and regional development organizations, multilateral organizations, advanced research institutes, the private sector and organizations.

**Agricultural Extension and Advisory Services**

Like R&D, agricultural extension and advisory services have passed through similar cycles of challenge and reform. The public services that dominate extension are plagued with widespread problems: limited funding, insufficient technology to promote, poorly trained staff, weak links to research, and limited farmer participation (World Bank 2005). Because previous approaches have been ineffective, most extension programs are moving away from centralized systems and trying to improve links with research and farmers (World Bank 2007b). Most programs widely acknowledge the need to build social capital among farmers, pay greater attention to the needs of women and youth, and facilitate better links to markets.

Despite widespread agreement on the need for change, it is clear that no single extension model is universally relevant. New models need to be developed, based not only on general principles but also on analyses of the specific farming systems and social conditions they are expected to address. New models are more important than ever, because extension services are shifting their focus and changing their roles to improve service provision and act as brokers to the more diverse set of clients seen in an AIS.

Better knowledge sharing and better use of available information and knowledge for desired changes are at the center of innovation processes. The role of information and communication technology (ICT) in producing and disseminating knowledge has expanded exponentially. ICTs offer striking opportunities to change how agricultural science, innovation, and development occur by enabling a variety of stakeholders to interact and collaborate in new ways to enhance the innovation process (box 6).

**Agricultural Education and Training**

Education and training institutions are especially significant in an AIS because they develop human resources and at the same time serve as a source of knowledge and technology. The absence or decline of these institutions leaves a large gap in a country’s innovation capacity. Even so, govern-

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**Box 6: Information and Communication Technology Enables Knowledge Exchange and Innovation**

For innovation to take place, effective bridging mechanisms are often needed to facilitate communication, translation and mediation across the boundaries between the various actors in agricultural research and development and between knowledge and action. Such facilitating and bridging mechanisms can include diverse innovation coordination mechanisms such as networks, associations, and extension services, but also ICT.

ICTs offer the opportunity to: improve knowledge flows among knowledge producers, disseminators and users, and e.g., among network partners; support the opening up of the research process to interaction and more accessible knowledge use; and more cost-effectively widen the participation of stakeholders in the innovation and governance process. ICTs have more often been associated with providing advanced services to number crunching and data management, geo-spatial applications, knowledge based systems and robotics, improved farm equipment and processes, but less often considered for connecting diverse innovation communities—whether at the local, sub-sectoral and national level.

ICTs that serve as information “collectors,” “analyzers,” “sharers,” and “disseminators” are already positively affecting agriculture interventions in developing countries. Affordable mobile applications in particular provide linkages to previously isolated actors: information on prices, good farming practices, soil fertility, pest or disease outbreaks, and extreme weather has expanded farmers’ opportunities to capitalize on markets, react to unfavorable agricultural conditions more effectively, and better interact with public service agents.

Satellite imagery and aerial photography have increased the capacity of scientists, researchers, and even insurance providers to study farm conditions in remote areas and assess damage from climatic challenges like drought. Increasingly affordable technologies like radio frequency identification tags and other wireless devices are improving livestock management, allowing producers to monitor animal health and trace animal products through the supply chain. A persistent barrier to innovation, the lack of rural finance, is also lifted by digital tools.

ment and donor investments in agricultural education and training (AET) have dropped to almost nothing since the early 1990s (World Bank 2008).

For AET, the primary constraint (among many) is that institutions have not kept pace with the labor market’s demands for knowledge and practical competencies, especially in agribusiness, business and program management, and the problem-solving and interpersonal skills crucial for actors to function in an AIS. Despite this poor performance, global experience shows that it is possible to build productive and financially sustainable education systems (World Bank 2007b). Besides the AET system in a number of developed countries (Denmark, Japan, the Netherlands, and the USA), developing countries such as India, Malaysia, Brazil, and the Philippines have established productive AET systems.

LIMITATIONS OF CURRENT INVESTMENTS FOR INCREASING INNOVATION IN AGRICULTURE

As shown in box 4, investments in science and technology have been a steady component of most strategies to improve and maintain agricultural productivity. The high returns and pro-poor growth emerging from investments in public agricultural research, advisory services, and education reflect a growing spectrum of initiatives to improve the response to clients’ demands, work with farmer groups, communicate better with partners, and collaborate with the private sector. Yet efforts to strengthen research systems and increase the availability of knowledge have not necessarily increased innovation or the use of knowledge in agriculture (Rajalahti, Woelcke, and Pehu 2005). As noted, complementary investments are needed to build the capacity for innovation across the spectrum of actors in the AIS and to develop an enabling environment for innovation to occur.

This sourcebook reviews and assesses experiences with those complementary investments. It outlines the needs, opportunities, and priorities for such investments and offers specific tools and guidance to develop interventions in different contexts. As emphasized in the next section—which offers more detail on the sourcebook’s contents and organization—this sourcebook reflects work in progress and an evolving knowledge base. The emerging principles it contains will change as practitioners learn and develop creative new approaches to innovation for agricultural development.

SOURCEBOOK MODULES

The content of this sourcebook is presented in a thematic modules (table 2). Modules 1 through 4 discuss the main investments related to innovation capacity (coordination and organization of stakeholders, agricultural education and training, and research and advisory services). Module 5 is concerned with the incentives and resources needed for innovative partnerships and business development, and Module 6 describes complementary investments that create a supportive environment for innovation. Module 7 provides information on assessing the AIS and identifying and prioritizing prospective investments, based partly on what has been learned from monitoring and evaluating similar efforts. A glossary includes a range of term related to agriculture, innovation, and development.

Each module generally has four parts:

- The Module Overview introduces the theme (a particular area of investment), summarizes the major issues and investment options, and points readers to more detailed discussions and examples in the thematic notes and innovative activity profiles that follow the overview. The overview provides substantive contextual information for each topic, including lessons from earlier approaches in national agricultural research systems (NARSs) and agricultural knowledge and information systems (AKIS).

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Source: Authors.
**Thematic Notes** (TNs) discuss technical and practical aspects of specific investment approaches and programs that have been tested and can be recommended (sometimes with provisos) for implementation and scaling up. The notes review the considerations, organizing principles, questions, performance indicators, and lessons that would guide the design and implementation of similar approaches or programs.

**Innovative Activity Profiles** (IAPs) describe the design and highlight innovative features of recent projects and activities related to the area of investment described in the module. The profiles give close attention to features that contributed to success and that technical experts can adapt for their own operations. The activities and projects described here have not yet been sufficiently evaluated to be considered “good practice” in a range of settings, but they should be monitored closely for potential scaling up. Their purpose is to ignite the imaginations of task managers and technical experts by providing possibilities to explore and adapt in projects.

**References and Further Reading** offer resources and additional information.

**THEMES COVERED IN THE MODULES**

Each sourcebook module covers a theme related to assessing and designing investments in a particular area integral to the AIS. The discussion that follows gives readers a broad idea of the contents and concerns of the modules. The nonagricultural and cross-cutting issues treated in each module are presented as well.

**Building the capacity to innovate (Modules 1–4)**

For an innovation system to be effective, the capacity of its diverse actors must be built and strengthened; many actors will increasingly possess a special mix of skills that contribute to the AIS in particular ways. Stronger technical skills must be complemented with functional expertise, because the new ways of working within an AIS require a range of skills: scientific, technical, managerial, and entrepreneurial skills and skills and routines related to partnering, negotiating, building consensus, and learning.

**Module 1. Coordination and Collective Action for Agricultural Innovation.**

A range of policies and effective organizations (or brokers/intermediaries) are needed to help organize often fragmented stakeholders with different assets, knowledge, and experience to participate in innovation processes and governance. Coordination and organization of stakeholders may be conducive to innovation in many ways, such as by building coherence and consensus-based priority setting; by strengthening the sharing of knowledge and resources; by strengthening collaboration through joint processes and products; and by reducing transaction costs and reaching economies of scale in extension and market activities.

Actors in an AIS do not innovate in isolation but through interacting with other actors—farmers, firms, farmer organizations, researchers, financial institutions, and public organizations—and the socioeconomic environment. In other words, agricultural innovation is an organizational phenomenon influenced by individual and collective behaviors, capabilities for innovation, and enabling conditions. Interaction, coordination and collective action are based above all the actors’ capacity to identify opportunities for innovation, assess the challenges involved, and access the social, human, and capital resources required for innovating, learning, and sharing information. Better coordination can improve the design and implementation of innovation policies by allowing more actors to voice their needs and concerns, resulting in more inclusive policies and faster diffusion of innovations. Stronger interaction and coordination can also induce all actors in an innovation system, particularly public research and extension organizations, to be more aware of and responsive to the needs and concerns of other actors, especially resource-poor households. Despite such advantages, interaction and coordination have been difficult to achieve for the same reasons that hinder collective action: opportunistic behavior; lack of trust, incentives, and capacity; and difficulties in setting and enforcing rules. Interaction and coordination in the innovation systems of developing countries are hampered as well by segmented markets, different technological regimes, lack of collaboration cultures, inappropriate incentives, weak channels of communication, and insufficient innovation capabilities.

Effective interaction, coordination, and collective action are based on existing capabilities, appropriate in-
centives, and the empowerment of individuals; thus they rely on voluntary action. Coordination and interaction can emerge spontaneously or be induced by specific public or private programs. Effective coordination requires (1) a committed and capable leadership; (2) appropriate incentives; (3) an enabling environment, in which important stakeholders that coordinate their activities have the mandate, culture, and freedom to participate; (4) stable support programs; (5) strengthening the capabilities for innovation and collective action; and (6) adaptation of public organizations to participate more effectively in innovation processes.

A range of policies, capacities, incentives and organizations are needed to support coordination and collective action at different levels of governance in the AIS. Without organizations (or brokers) to address social and resource imbalances and transaction costs, prospects for participating in innovation processes and systems are limited, especially for poor people. Effective organizational innovations help to organize stakeholders with different assets, knowledge, and experience. The organizational innovations (committees/councils, platforms/networks, and diverse associations) reviewed in this module show that many innovations are not planned in detail beforehand but result from the adaptation of organizational structures in response to emerging problems or opportunities. They also show that creative and committed individuals guide the adaptation and that an enabling environment allows the organizations to change.

Module 2. Agricultural Education and Training to Support Agricultural Innovation Systems

Agricultural education and training (AET) institutions are especially significant in an AIS because they develop human resources and at the same time serve as a source of knowledge and technology. AET organizations require overall greater investments as well as reforming/reorienting (e.g., long-term reform processes, curriculum reform, technician training approaches, as well as on-the-job training) to better serve the needs of a diverse cadre of AIS actors.

Agricultural Education and Training (AET) has a major role as a creator of capacity and supplier of the human resources that populate key segments of the AIS and enable that system to function more effectively. Past neglect and low levels of investment have prevented many national AET systems from equipping graduates to meet the needs of modern agriculture and contribute to the AIS. Aside from the technical knowledge that is the traditional focus of AET, graduates require the knowledge and tools to recognize innovative ideas and technology, catalyze communication between other AIS actors, and provide feedback to researchers and investors. Graduates particularly require new, “soft” skills, such as leadership, communication, negotiation, facilitation, and organizational capabilities. Employers increasingly demand these skills, which foster active participation in the AIS.

Serious constraints to quality education and training include weaknesses in policies that guide AET, the divided responsibilities for parts of the AET system, poor governance of AET institutions, continuing isolation of AET systems from key stakeholders, and serious underinvestment in AET systems. The major priority for reform is to develop a policy framework and (innovation) policy management capacity to guide AET. This reform underpins all others; it has wide implications for AET, interministerial cooperation, financing, and stakeholder involvement. Another investment priority—wide-ranging, systemic reform—requires internal and external consultations with stakeholders and an analysis of gaps between stakeholders’ expectations and current academic programs. Other priorities for investment include reforming curricula and teaching methods; building capacity and stakeholder partnerships for technical education and training; and developing effective in-service and life-long learning capacity among public workers who interact frequently in the AIS. Such reforms can be supported by investments in capacity building and infrastructure for ICTs to facilitate learning, research, and global and local networking and communicating. Investments in accreditation or in a regional resource for advanced degrees may also improve the likelihood that AET delivers content that meets stakeholders’ needs.

Regardless of the chosen reform target, any change initiative will be subject to resistance, and leadership and commitment will be needed to see reforms through to the end. Depending on the location, capacity, commitment, and leadership for change, the time focus may shift to require longer-than-anticipated support; in other cases, reforms and changes may proceed faster than expected. A broad lesson for practitioners in planning reform programs of any length is to pay close attention to building constituencies of stakeholders at all levels to help ensure the program’s sustainability.
Module 3. Investment in Extension and Advisory Services as Part of Agricultural Innovation Systems

Demand-driven, pluralistic extension and advisory services can become nodes for exchanging information and services that help put knowledge to use. They would be well positioned to facilitate and support multi-stakeholder processes and the heterogeneous client base of an AIS. New models are more important than ever, because extension services are shifting their focus and changing their roles to improve service provision and act as brokers to the more diverse set of clients seen in an AIS.

Extension and advisory services are integral to the AIS, where now more than ever they play a brokering role, linking key actors such as producer organizations, research services, and higher education. This module looks at the history and current status of extension and advisory services and examines important topics such as pluralism, new roles for extension, new kinds of service providers, ICTs, and agribusiness.

For strong extension and advisory services, it is important to have coordination and linkage within pluralistic, multistakeholder AIS. Less traditional actors such as farmer organizations and agrodealers are important extension and advisory service providers who are vital to include in the design of investments and programs. Extension and advisory services must be ever-adapting to the needs of clients, and they must monitor and evaluate their services.

Perhaps the broadest challenge is the tremendous need for new capacities within extension. Throughout the developing world, evolving demands and new roles for advisory services in the wider innovation system will require investments in the capacity of individual extension workers and organizations for value chain approaches, in market-oriented extension, in group and organizational development, in agribusiness, and in mechanisms to share information (networks, platforms, and the like). Recent global developments require advisory services to focus on climate change, food security, and equipping rural people to deal with risk in general.

To better serve their constituencies and influence policies, advisory services need a stronger voice at the global and regional level. There is a need for evidence-based direction regarding investment priorities and programming options for agricultural advisory services within innovation systems. Policy issues related to pluralistic advisory services and extension include the changing roles of various extension providers, the comparative advantage for different providers in carrying out specific extension functions and advisory services, sustainability, and equity. Paradigm shifts—from the perception that research knowledge can drive innovation to the notion that change in the whole system is needed for innovation—must take place not only in the programs and the thinking of field staff but in the thinking of extension administrators and policy makers.

Module 4. Agricultural Research within an Agricultural Innovation System

A strong science and technology system contributes to innovation and sustainable, equitable agricultural development. Agricultural research systems are the source of new knowledge and the resulting products, services, and management practices that enable productivity to grow. The performance of research systems can be enhanced through improved demand articulation, more effective interface with international and national institutional partnerships, and better market integration. Investments in capacity and in mechanisms for articulating demand and developing interfaces with other actors (for example, through co-design, innovation platforms, alliances and consortia, and technology transfer and commercialization) are at the center of these reforms.

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.

Module 5. Incentives for Innovation Partnerships and Business Development

Economic change entails the transformation of knowledge into goods and services through innovation, partnerships and business enterprises. Strong links between knowledge and business development are a good indication of the vitality of an AIS. The private sector contributes to innovation through service provision, technology development and commercialization, or through other business related innovation. Partnerships and business development may be promoted via incentives—such as support for technology commercialization via technology transfer offices, incubators, and science parks, or support for business via innovation funds, risk capital, and other resources to initiate and sustain novel partnerships.

Governments in developing countries increasingly intervene actively in supporting private sector development through diverse means. Public investments in business development can direct private investments towards areas of significant public interest and areas where the private sector alone would generally underinvest. They can facilitate or stimulate private investment through a conducive policy, legal, and institutional environment. Public investments for business development can also complement private investments (for example, by funding services or basic research). Such public-private partnerships need to become a strategic element of the agricultural development agenda. Formal technology transfer mechanisms (IPRs, licensing) offered through specialized technology transfer offices are critical to engage effectively in PPPs and disseminate technology through market channels.

The appropriate funding mechanisms to support innovation by collaborating public institutions, private entrepreneurs, and other actors depend on the public good to be produced and the role of the public sector. Useful alternatives include specialized innovation funds and matching grants to provide incentives for collaboration and risk taking. The use of venture capital funding has been limited in developing countries, but small and medium agricultural enterprises require risk capital to capture opportunities presented by agricultural innovation.

Support for business incubation helps to scale up small and often newly formed enterprises that bring innovative technologies and services to market. Developing countries require broader, less intensive, and more diverse incubator services to develop entrepreneurial, innovative cultures and business environments. Agricultural clusters foster innovation through proximity; they encompass interdependent firms in a value chain, service providers, and associated institutions. Cluster-based approaches have increased agricultural productivity, innovation, and business formation.

The key policy issues for agricultural business development and PPPs involve their potential for altering development priorities, the potential welfare effects of agricultural innovation and growth driven by private interests, welfare concerns related to gender and social equity, and prospects for building a “shared responsibility system” capable of balancing the sometimes divergent interests of the public sector, private sector, and civil society. Finally, in an environment characterized by increasing private involvement in agricultural innovation, very clear criteria will be needed to determine when public intervention is justified and at what level. Every publicly supported partnership or business development program must have a clear time frame and exit
strategy. If the temporary nature of public involvement is not clear at the outset, private investors' decisions and business plans will be biased. The sustainability of social and environmental services, on the other hand, is often assured only through long-term public support.

Module 6. Creating an Enabling Environment for Agricultural Innovation

Innovation and business development by different stakeholders does not occur without complementary investments to create a supportive environment. Enabling conditions in a given context depend on a (innovation) policy mix, innovation governance arrangements and a diverse set of regulatory matters (for quality and safety, intellectual property, and biosafety). Other enabling investments, such as infrastructure, market institutions, and financial services, have synergistic effects with other instruments such as innovation funds. Given the resource limitations and numerous choices, investments in an enabling environment must be prioritized and sequenced with great care.

The “enabling environment” for agricultural innovation encompasses factors that influence agricultural innovation positively but are controlled by policy domains other than agricultural innovation policy. An agricultural innovation policy seeks coordination with these other domains to ensure that together they enable agricultural innovation. Cross-cutting policy issues affecting agricultural innovation include policies to reduce poverty and sustain the environment, to foster collaboration between the public and private sectors, and to build social capital more generally. Three clusters of enabling factors for agricultural innovation appear to require attention and investment in most developing countries: (1) innovation policy and corresponding governance structures to strengthen the broader framework for agricultural innovation policies; (2) regulatory frameworks that stimulate innovation directly (such as IPRs) or indirectly (standards that stimulate trade) or steer innovation towards certain preferred outcomes (safer food); and (3) accompanying agricultural investments in rural credit, infrastructure, and markets.

Innovation policy is a new area, and in most countries the governance structure for innovation is only starting to emerge. A particular challenge is where to assign responsibility for innovation policy within the government structure. Some countries delegate this task to the ministry in charge of science and technology, while others establish a higher-level entity that brings relevant ministries together to coordinate national innovation policy. In most countries, the overall objective of the national innovation policy is to facilitate the transition toward a knowledge economy, resulting in increased competitiveness and sustainable economic growth. A national innovation policy defines the roles and functions of actors and stakeholders within the national innovation system (NIS), provides an overall framework for innovation policies specific to particular sectors, and sets priorities across sectors and technologies. It creates positive conditions for innovation by investing in public goods essential for an innovative knowledge economy.

Regulatory frameworks important for agricultural innovation include those for IPR; biosafety; agricultural health and food safety standards and regulations. Countries will need assistance to develop legislation, assess the options from which they can choose, develop their regulatory agencies, and invest in standards-related infrastructure.

Better coordination of agricultural innovation investments with accompanying rural investments should lead to greater synergy and impact. Investments in rural financing systems will adopt a more holistic approach to financial services, including credit, savings, money transfers, leasing, and insurance. Investments in roads and market institutions and infrastructure help to improve agricultural productivity, reduce marketing costs, increase profit margins, and open up new opportunities for innovation.

These policies, investments, and regulatory reforms will trigger significant changes, such as improving the access of agricultural products to foreign markets, increasing private investment in agricultural R&D, and fostering the use of more sustainable agricultural practices. Policy measures will be needed to ensure that people are not left behind and make the transition to more promising economic activities.


AIS investments must be specific to the context and respond to the stage of development in a particular country and agricultural sector, especially the AIS. Given that optimal human and financial resources are rarely available, an incremental approach is advisable. The scale of operations is also likely to vary from local/zonal to subsectoral or national. This variation requires investments to be as-

Photo: Tsega Wolday/Bioversity International.
sessed, prioritized, sequenced, and tailored to the needs, challenges, and resources that are present.

The identification and design of appropriate interventions begins with a good understanding of the level of development and the strengths and weaknesses of the AIS. The status of an AIS and its critical needs can be assessed in several ways and at several levels. Not only are new sorts of information required to develop an AIS, but that information must be generated and used in new ways. Knowledge-based decisions to support technical and institutional innovation emerge from analyses of information and group communication processes. In innovation systems, tasks such as policy assessment, monitoring, and evaluation are vital to maintaining learning, performance, and accountability.

This module examines processes to inform decision making and manage innovation at four generally defined levels of the innovation system for agriculture: policy, investment, organization, and intervention. The module identifies methods relevant at each level for assessing, prioritizing, monitoring, and evaluating innovation processes. For example, at the policy level, international and cross-sectoral comparative analyses may be used (such as benchmarking) and combined with multistakeholder policy dialogues and foresighting studies to inform future scenarios for specific development issues or subsectors. At the organizational level, methods include multi-institutional and organizational performance assessments involving innovation surveys and network mapping. At the level of specific programs or interventions, assessment tools for strengthening the involvement of end-users or farmers in value chains include gender analysis and support for self-organizing networks, among others. Still other methods are relevant at all levels of the innovation system for effective performance management, accompanied by reporting arrangements that ensure accountability. The module features different tools and methods such as assessments methods for AIS and organizations, NetMap tool, foresighting methods, and a diverse set of methods for M&E.

Nonagricultural and Cross-cutting Issues

Although the sourcebook focuses on innovation in agriculture, it draws on experience and lessons from other sectors, not least because so many “nonagricultural” issues impinge on agriculture and innovation. Such issues include rural finance, business development, innovation policies, and the governance of innovation, among others.

The sourcebook addresses three major cross-cutting themes—the role of the public and private sector, climate change and green growth, and gender.

Box 7: Cross-cutting Themes Addressed in this Sourcebook

**The role of the public and private sector.** The public sector is expected to remain an important provider and/or funder of R&D, education, and extension services in developing countries. Ninety-four percent of the investment in agricultural R&D in the developing world still comes from public coffers (World Bank 2007b). Yet if markets now drive much of the agenda for agricultural R&D, and new actors are more prominent in agriculture, what is the proper role of the public sector? Each module examines the roles of the public and private sector with a view to answering that question.

**Climate change and green growth.** Climate change adaptation and mitigation are key goals of an agricultural knowledge system. Technical as well as organizational innovations (for example, the use of climate-smart and green technologies, coupled with inclusive and effective approaches on knowledge dissemination and adoption) are required to identify and develop appropriate solutions that contribute to adaptation, mitigation, and green growth. The modules describe institutional approaches that lend themselves well to generating and adopting climate-smart solutions.

**Gender.** The AIS approach argues that diversity, inclusion, and participatory approaches are critical to building the quality of social capital needed for resilient and sustainable innovation systems. It takes into account the many actors along the value chain; diverse organizational forms to facilitate education, research, and extension systems; and the practices, attitudes, and policies that frame agricultural production and trade. Every module addresses gender issues through examples and/or policy interventions.
change, and gender—as appropriate (and when examples have been identified). These issues are briefly introduced in box 7.

THE SOURCEBOOK AS A LIVING DOCUMENT

To the extent possible, the modules in this sourcebook reflect current knowledge and guidance for investments to support innovation systems in agriculture. Their content is based on the expert judgment of the authors and thematic specialists, as well as reviews by experienced specialists. Yet important gaps in knowledge remain, and new knowledge will emerge from approaches that are just now being devised and tested. For example, impact assessment methods and good M&E practices for an AIS are two areas in which much more knowledge is needed. Future iterations of this sourcebook will also benefit from additional examples of integrated AIS investments to strengthen innovation capacity in related areas such as education, research, advisory services, and brokering, among others.

This sourcebook is intended to be a living document that remains open to dialogue and new, imaginative approaches to innovation for agricultural development. Its primary home is not on the bookshelf but online, where it will be updated and expanded as new experience is gained and new approaches and initiatives arise. The authors strongly encourage readers to update, verify, and offer feedback on the information here. Readers are encouraged to adapt key principles and relevant guidelines to their individual agricultural projects and programs—and share the results widely.

NOTES

1 Adapted from Bernet, Thiele, and Zschocke (2006); Hall, Clark, and Naik (2007); World Bank (2006); A. Hall (personal communication); and R. Rajalahti (personal communication).

2 In contrast to the CGIAR’s origins in the 1960s and 1970s as a mechanism for funding research divided largely along commodity and geographic lines. For more information on the change management process and on how the CGIAR has changed as agriculture, approaches to R&D, and approaches to funding R&D have changed, see www.cgiar.org.
References and Further Reading


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