Strengthening National Agricultural Research Systems

Policy Issues and Good Practice

Derek Byerlee
Gary E. Alex
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The World Bank
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Cover: Pigeonpea farmers near Makindu, Kenya, learn that they have much to gain from adopting extra-short-duration varieties. Photo from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

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## Contents

Acknowledgments vi
Foreword vii
Abbreviations and Acronyms ix

Executive Summary 1
Introduction and Objectives 9

Chapter 1 Recent Evolution of National Agricultural Research Systems 11
  Investment in National Agricultural Research Systems 11
  Payoffs to Research Investments 13
  The Changing Agricultural Research Agenda 14
  Emerging Institutional Challenges in National Agricultural Research Systems 16

Chapter 2 National Research System Development: Issues and Good Practice 18
  Conceptual Overview of the Emerging National Agricultural Research Systems 18
  Coordination in the Emerging National Agricultural Research Systems 21
  Competitive Funding of Research 22
  Integrating Universities in the NARS 24
  Increasing the Role of the Private Sector 25
  Linking the National Agricultural Research Systems to Regional and International Research Systems 28

Chapter 3 Strengthening Public Research Institutes: Issues and Good Practice 33
  Responding to the Funding Crisis 33
  Organizing National Agricultural Research Institutes for Increased Efficiency 39
  Institutionalizing Research Planning and Evaluation 42
  Upgrading Human Resources Management 47
  Improving Client Orientation and Technology Transfer in National Agricultural Research Institutes 50

Chapter 4 The World Bank's Role in Strengthening National Research Systems 57
  Evolution of Bank Support to Research 57
  Key Elements of Current Bank Strategy 61
Supporting New Research Priorities 64
Implications for the Bank 66

Annexes
1 Main Recommendations from Reviews of World Bank Research Projects 72
2 World Bank Funding for Agricultural Research by Year and by Geographic Region 76
3 Illustrative Project Performance Indicators for Agricultural Research Projects 78

Bibliography 83

Boxes
1.1 Crop improvement research: An institutionalized success story 14
1.2 Crop and resource management research: A continuing challenge 15
1.3 The diversity of National Agricultural Research Systems 17
2.1 Funding versus execution of research in Australia 20
2.2 Building consensus: The importance of a strategic vision 23
2.3 Why have universities been underutilized in national agricultural research systems? 25
2.4 Research foundations: A diversity of approaches 27
2.5 Technology spill-ins: Spreading research benefits beyond borders 29
2.6 Collaborative partnerships between IARCs and NARSs 30
2.7 Latin American Regional Research Fund 31
3.1 Funding reliability in the short term 34
3.2 Five key questions to ask on cost recovery in public research institutes 37
3.3 Why is research different from many public sector activities? 39
3.4 Agricultural research and poverty reduction 47
3.5 Farmer-run research: Experience with the Comité de Investigación Agropecuaria Local 52
3.6 Links to farmers' organizations 52
3.7 Improved research-extension linkages: The case of Ghana 53
3.8 Serving the "policy client" 55
4.1 Major recommendations of the Operations and Evaluation Department review of agricultural research projects 60
4.2 Problems identified in a 1997 review of agricultural research projects 61
4.3 An emerging challenge: The national agricultural research systems of Eastern Europe and Central Asia 64
4.4 Global Forum on Agricultural Research 64
4.5 Geographic information systems: A potentially powerful new tool for agricultural research 66

Tables
1.1 Number of scientists employed by the public sector of national agricultural research systems 12
1.2 Public agricultural research expenditures: Global trends 12
1.3 Intensity of public sector investment in agricultural research 13
3.1 Definition of "autonomy" in terms of the types of flexibility required for various management functions 40
3.2 Summary of monitoring and evaluation indicators and their implementation in agricultural research 46
Contents

4.1 Summary data on World Bank agricultural research projects 58
4.2 Regional share of World Bank loans for agricultural research 59
4.3 List of operational strategies identified in 1980 World Bank policy guidelines 60
4.4 Trends in institutional issues emphasized in the current World Bank portfolio of research projects 61

Figures

2.1 Traditional view of a national agricultural research system 19
2.2 New perspective on national agricultural research systems 19
4.1 Percentage of World Bank agricultural loans for research and extension 58
4.2 Geographic distribution of World Bank agricultural research funding between 1981 and 1996 59
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Foreword

The financing of agricultural research is one of the most important components of the World Bank’s rural sector portfolio. Support to the research subsector has seen a sharp change in emphasis in the 1990s toward supporting institutional reform and pluralism in funding and executing research and toward developing sustainable funding mechanisms for public sector research. In light of these changes and in response to a recent comprehensive review of the subsector by the Operations Evaluation Department (OED), the Bank has been developing new forms of support to agricultural research.

This report has two objectives. First, it provides a brief review of recent trends and key policy issues in strengthening national agricultural research systems—broadly defined to include national research institutes, universities, the private sector, and nongovernmental organizations. Second, it synthesizes “good practice” in ongoing institutional and policy reforms in the subsector. The report explores agricultural research policy issues and provides a resource on selected research policy and management issues for Bank staff and partners in borrowing countries. Most of the practices presented here have been incorporated in recent Bank projects in various forms. For complex issues, such as agricultural research policy, best practices are often very situation specific.

The report contains four parts. Chapter 1 provides a brief overview of the recent evolution of national research systems. Chapters 2 and 3 are the main body of the report. Chapter 2 synthesizes policy issues and good practices for developing national agricultural research systems within an emerging global agricultural research system. While there is growing participation from diverse partners in research funding and execution, the public sector will continue to be central in undertaking research on the emerging challenges of sustainable agricultural intensification, poverty alleviation, and conservation of natural resources. Chapter 3 focuses on the key policy and institutional reforms needed to strengthen these public sector research institutions. The report provides the underlying rationale for selecting good practices and discusses their applicability in specific situations. Chapter 4 discusses implications for the Bank in its ongoing efforts to strengthen national research systems.

Bank support for agricultural research will be central to its objectives of alleviating poverty and conserving natural resources. However, agricultural research policy and best practices will continue to evolve in response to the changing roles of the public and private sectors, new institutional mechanisms for funding and executing research in the public sector, and changing demands on research systems. Through its recently formed thematic team on agricultural
knowledge and information systems, the World Bank will closely monitor ongoing experience in research projects, and modify best practices in light of these experiences.

Alex F. McCalla
Director, Rural Development Family

Michel Petit
Director, Agricultural Research and Extension Group
# Abbreviations and Acronyms

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>AFR</td>
<td>Africa Region of the World Bank</td>
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<tr>
<td>AgGDP</td>
<td>Agricultural gross domestic product</td>
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<td>ARF</td>
<td>Agricultural research fund</td>
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<td>ARI</td>
<td>Agricultural research intensity</td>
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<td>ASARECA</td>
<td>Association for Strengthening Agricultural Research in Eastern and Central Africa</td>
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<tr>
<td>CAS</td>
<td>Country assistance strategy</td>
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<tr>
<td>CEO</td>
<td>Chief executive officer</td>
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<td>CG</td>
<td>Competitive grant</td>
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<tr>
<td>CGIAR</td>
<td>Consultative Group on International Agricultural Research</td>
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<tr>
<td>CIAL</td>
<td>Local agricultural research committee (Comité de Investigación Agropecuaria Local)</td>
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<tr>
<td>EAP</td>
<td>East Asia and Pacific Region</td>
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<tr>
<td>ECA</td>
<td>Europe and Central Asia Region of the World Bank</td>
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<tr>
<td>EDI</td>
<td>Economic Development Institute of the World Bank</td>
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<tr>
<td>ESDAR</td>
<td>Agricultural Research and Extension Group of the World Bank</td>
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<tr>
<td>FAO</td>
<td>Food and Agriculture Organization</td>
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<td>FFA</td>
<td>Framework for Action</td>
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<td>FSR</td>
<td>Farming systems research</td>
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<tr>
<td>FUNDAGRO</td>
<td>Foundation for Agricultural Development of Ecuador</td>
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<td>FUNDEAGRO</td>
<td>Foundation for Agricultural Development of Peru</td>
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<tr>
<td>GDP</td>
<td>Gross domestic product</td>
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<tr>
<td>GIS</td>
<td>Geographic information system</td>
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<td>GREAN</td>
<td>Global Research on the Environment and Agricultural Nexus program proposal</td>
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<td>IARC</td>
<td>International agricultural research center</td>
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<td>IDB</td>
<td>Inter-American Development Bank</td>
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<tr>
<td>IFPRI</td>
<td>International Food Policy Research Institute</td>
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<td>IPM</td>
<td>Integrated pest management</td>
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<td>IPR</td>
<td>Intellectual property rights</td>
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<tr>
<td>ISNAR</td>
<td>International Service for National Agricultural Research</td>
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<tr>
<td>LAC</td>
<td>Latin America and the Caribbean Region of the World Bank</td>
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<tr>
<td>M&amp;E</td>
<td>Monitoring and evaluation</td>
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<tr>
<td>MNA</td>
<td>Middle East and North Africa Region of the World Bank</td>
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<tr>
<td>NARI</td>
<td>National agricultural research institute</td>
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<td>NARS</td>
<td>National agricultural research system</td>
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<tr>
<td>NGO</td>
<td>Nongovernmental organization</td>
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<td>NRM</td>
<td>Natural resource management</td>
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<td>NRMR</td>
<td>Natural resource management research</td>
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<tr>
<td>OED</td>
<td>Operations Evaluation Department</td>
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<td>PRA</td>
<td>Participatory rural appraisal</td>
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<tr>
<td>Abbreviation</td>
<td>Description</td>
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<tr>
<td>PROCI</td>
<td>Program of Regional Cooperation</td>
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<td>PROCIANDINO</td>
<td>Andean Program of Regional Cooperation</td>
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<tr>
<td>RARA</td>
<td>Regional agricultural research association</td>
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<tr>
<td>RELC</td>
<td>Research-Extension Liaison Committee</td>
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<td>RDC</td>
<td>Research and Development Corporations of Australia</td>
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<td>RDV</td>
<td>Rural Development Family (formerly Agriculture and Natural Resources Department, or AGR) of the World Bank</td>
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<tr>
<td>R&amp;D</td>
<td>Research and development</td>
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<tr>
<td>SAS</td>
<td>South Asia Region of the World Bank</td>
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<tr>
<td>SPAAR</td>
<td>Special Program for African Agricultural Research</td>
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<tr>
<td>TFP</td>
<td>Total factor productivity</td>
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<tr>
<td>UNEP</td>
<td>United Nations Environment Programme</td>
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<tr>
<td>USAID</td>
<td>U. S. Agency for International Development</td>
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<td>WANA</td>
<td>West Asia and North Africa Region of the World Bank</td>
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Executive Summary

This report reviews key issues facing research managers, policy makers, and the development assistance community in positioning national agricultural research systems to address the challenges of the next decade. The review is motivated by the sharp fall in investment in agricultural research in many countries in the 1990s, following a period of rapid growth since 1970, combined with management and organizational problems in many research systems that challenge the sustainability of agricultural research capacity.

Strengthening agricultural research systems will be central to current World Bank efforts to revitalize agriculture and rural development over the next decade. Sustainable intensification of agricultural systems through rapid and broad-based technological change is critical to solving global problems of food security, poverty alleviation, and conservation of natural resources.

The World Bank has been an active participant in the growth of national agricultural research systems (NARSs), lending nearly $4 billion for their support since 1981. The emphasis in these projects has steadily evolved from one of investment in research infrastructure and human resources development to improving research management and institution building within a pluralistic national research system. Recent Bank lending programs have often included downsizing and consolidation. This is a sharp departure from the agricultural research policy approved by the Bank in 1980, that emphasized quantitative targets for expansion of research systems.

The paper discusses current issues in the sustainable development of NARSs and identifies "good practice" for selected issues in agricultural research policy and management. Good practice in agricultural research varies widely across countries depending on the stage of development of the NARS, institutional history, the type of agriculture, and the size and political organization of the country. The paper (1) reviews recent changes in NARSs capacity and performance; (2) examines organizational and conceptual challenges and good practice in moving from a focus on public research institutes to emphasizing the development of national research systems that recognize key roles for universities and the private sector; (3) examines key funding, institutional, organizational, and management issues and good practice in reforming public research institutes; and (4) discusses the consequent implications for World Bank support to agricultural research.

Fostering the Evolution of National Research Systems

NARSs have evolved rapidly over the past three decades, especially in the quantitative dimension. In aggregate, public research systems in the developing world employ over 100,000
scientists and manage an annual investment of over $8 billion. This investment now exceeds that in industrialized countries. But over the past decade, public research systems almost everywhere have faced a crisis of confidence reflected in stagnant or reduced funding and severe restrictions on operating costs. The private sector has potential to fill some of the gap and has expanded rapidly from a very small base to account for about 10–15 percent of resources invested in agricultural research in developing countries.

The Changing National Agricultural Research Systems Environment in the 1990s

In recent years the economic and technical environment for agricultural research has also changed drastically. Trade liberalization has shifted economic incentives and improved technology is now a critical factor in a country's ability to exploit its comparative and competitive advantages. Technological needs are changing toward more knowledge- and skill-intensive agriculture and more complex farming systems. Important changes in the technology for research itself, especially the new biotechnologies and informational technologies, are raising new issues in organizing national research systems, related to economies of size, international collaboration, and public-private linkages.

These increasing demands on research systems contrast with the lack of institutional innovation in research-system management and organization and the stagnation or decline in funding for agricultural research. The substantial investment in NARs over the past two decades, although providing high payoffs, has not yet resulted in the institutional capacity to sustain those payoffs in a rapidly evolving technical and policy environment. Many systems are suffering a crisis of management, with top-heavy bureaucracy, centralization of decision-making, and lack of incentives for the innovation process so essential for research.

Emphasis on building agricultural research capacity has now shifted from exclusive attention to developing national agricultural research institutes (NARIs) to strengthening national research systems, broadly defined to include the NARI, universities and the private sector (both for profit and nonprofit). The challenge is to develop a well-articulated research system to meet national objectives for the sector by developing innovative institutional models that encourage participation of alternative research funders and suppliers, bringing more resources into the research system, and exploiting complementarities among various participants at the national and international levels.

Key Elements of the New National Agricultural Research Systems Paradigm

The emerging concept of a NARSs is characterized by seven key elements:

- A conceptual and increasingly, institutionalized separation of research funding from research execution, each of which requires distinct skills and inputs. Research funding and the setting of broad priorities for research is a policy issue, while research execution by alternative suppliers is an efficiency issue.
- A recognition of the pluralistic institutional structure of a NARS that includes universities, the private sector, farmer organizations, and nongovernmental organizations (NGOs), that allows additional scientific skills to be tapped and matched with needs, thus increasing research efficiency.
- A sharper focus of public funding for research on public goods and diversification of funding support for public research institutes. There is a strong case for public-sector funding of basic and strategic research (long-term research with uncertain payoffs and high spillovers), research on problems of small-farm agriculture (high transactions costs for farmers to organize their own research), and research on natural resource management (positive environmental externalities).
- A recognition of the complementary roles of public and private sector research and...
Executive Summary

Development (R&D) and the potential efficiency gains through private-public sector collaboration in both the funding and execution of research due to the complementary skills and resources in each sector.

- Increased flexibility and institutional autonomy in public research institutions combined with increased accountability to promote results-oriented institutions, characterized by business-oriented management of human, financial, and physical resources.

- The involvement of stakeholders, especially the clients of the research system, in research governance, priority setting, execution, financing, and evaluation so that institutions within the NARSs become more responsive to their needs. The institutional models for achieving this include full or partial funding of research by farmers and other clients, involvement of farmers and farmers' organizations in governance of research organizations, and various types of contractual relationships with clients in executing research.

- New models for technology transfer that move beyond the traditional research-extension chain to involve farmers, NGOs, and the private sector in a variety of formal and informal partnerships, and information dissemination and feedback mechanisms.

Good Practice in the Sustainable Evolution of National Agricultural Research Systems

In the new way of thinking, NARS are almost invariably complex with wider and more diverse institutional participation in both research funding and execution. Such complexity requires increased attention to strengthening coordination and interaction within the system.

First, each NARS needs to develop a broad "vision" of the future evolution of the research system over the next 10-20 years that succinctly outlines the changing demands for technology; the expected future roles of the public and private sectors and their interaction; the comparative advantage and mandates for central, state, and local research institutes; sustainable funding mechanisms; and linkages with clients, technology transfer agencies, and the global agricultural research system. Such a vision will require considerable dialogue among all stakeholders to ensure broad consensus on the future direction of the NARS. This vision may be developed by a small apex body that is broadly representative of key stakeholders and that can act as a national forum for developing and coordinating research strategies, formulating policies, and financing of research. There are many other less formal institutional mechanisms for system coordination, and in large countries several mechanisms may be needed.

Second, all NARSs will have to seek means to increase private-sector investment in R&D and enhance public-private sector complementarity and partnerships. A variety of mechanisms can be employed, including investment in strong basic and strategic research programs in the public sector, implementing institutional mechanisms and legal frameworks for public-private joint ventures, strengthening and enforcing intellectual property rights, and relaxing regulations on approval and release of new technologies and on importing technology (but ensuring that key public health and national food security concerns are protected). In some situations, private foundations can successfully support agricultural research, especially if they are well endowed and have strong local support.

Third, universities are a valuable but underutilized resource that have much potential to contribute to the evolution of a strong NARS. This will require policy and structural reforms such as competitive funds, and collaborative research networks to expand university involvement in research. Universities themselves will have to adopt policies and develop capabilities to promote and conduct research. In addition, upgrading of universities will be critical to improving the human resource capacity for scientific research at all levels of the
NARS. Strengthening of universities in both research capacity and human resource development is, therefore, integral to strengthening NARS.

Fourth, governments can shift more of their funding through competitive grants in order to mobilize underutilized resources, promote research partnerships, improve research quality, and move research resources toward agreed national priorities. Competitive grant systems work best in institutional structures where there is substantial management flexibility and independence from political and bureaucratic interference. However, competitive grants cannot, and should not, substitute for institutional development and longer-term investments in developing research infrastructure, nor are they as relevant to small NARSs, where higher administrative costs and limited potential for competition reduces their value.

Finally, all NARSs will have to integrate with the emerging global agricultural research system (composed of international centers, regional centers and networks, large multinational R&D programs, and a diverse array of NARs) to keep abreast of rapid advances in scientific knowledge, and to improve the cost effectiveness of technology generation by capturing "spill-ins" and through collaborative research. A variety of institutional mechanisms, such as international and regional networks and collaborative research programs with international centers and advanced research institutes, can be employed. Regional research initiatives, including regional networks, joint research initiatives, and the establishment of regional research funds, will also play a role, provided they are cost effective and are NARS-driven and funded.

Increasing the Efficiency and Effectiveness of Public Research Institutions

Although NARSs will become more institutionally diversified in both the funding and execution of research, public research institutes (the NARIs), which command a considerable share of global human and financial resources for agricultural science, will be key to strengthening most agricultural research systems. The pressure on research funding over the past decade and erosion of confidence in public research organizations is a serious threat to the viability of many national agricultural research institutes (NARIs). Institutional reform of public research institutes is needed to improve their efficiency and effectiveness through streamlining research priorities, reforming management and incentive systems, and building links to external partners.

Developing Sustainable Funding

Most NARIs depend largely on public funding and/or donor support, both of which are subject to long-term erosion and uncertainty. This requires two responses. First, NARIs must build political support for public funding of research by increasing public awareness—at all levels—on the role and impacts of research, developing strong and articulate client organizations that can act as a lobby for agricultural research, and by reforming the management and effectiveness of NARIs to make them more attractive investments.

Second, all public research organizations will need to diversify funding from their almost complete dependence on government budgetary appropriations. One approach is through implementing cost recovery for some products and services, such as royalties on research products, user fees for nonresearch products and services, and joint ventures with the private sector. Although this commercialization of research products and services can provide important contributions to operating costs, it should be approached with caution, as it can quickly distort program priorities and attention. Public sector institutes require clear and transparent policies for ensuring that commercialization is consistent with the public interest, applying intellectual property rights to protect technologies, providing access to protected technologies for research purposes, and sharing the revenues generated. Special
caution is needed in commercializing non-research products and services to ensure that this is complementary, not competitive, to the main business of research.

NARIs can also diversify funding by encouraging, where feasible, farmer financing of research through levies, together with mechanisms to ensure farmer participation in setting priorities for the research that they fund. This approach will work best if farmer contributions are matched by government funds as an incentive for farmers to fund longer-term research, or research with broader societal benefits.

Organizing Public Research Institutions

Most public research organizations are part of, or closely associated, with government ministries. Excessive political and bureaucratic interference in their management is one reason for lack of effectiveness of some NARIs. Institutional reform requires that NARIs be provided greater autonomy (up to the creation of independent research corporations) to give them the flexibility to adopt business practices for financial and personnel management (including setting salary levels) more conducive for attracting high-quality scientists and utilizing them effectively. Success in providing autonomy will depend on (1) the appointment of members of governing boards in their individual professional capacity, (2) the involvement of diverse stakeholders in governance, (3) obtaining expert advice on public sector reform to define rules and regulations for managing financial and human resources and assets, and (4) developing performance indicators to ensure accountability to research funders.

Many NARIs have highly centralized organizational structures. Each NARI will have to rationalize the level of centralization in research funding and execution according to the potential for technology spillovers, economies of size in research organizations, and the need to build local political support for research funding. Centralized NARIs will probably become more specialized in basic and strategic research (with substantial economies of size), and management of national research networks (to promote spillovers), while much of the applied and adaptive research will be decentralized to administratively independent regional research centers, in which farmers are involved in funding, priority setting, and governance.

Finally, efficiency of most research organizations can be enhanced through cutting redundant and nonperforming staff, and consolidating research programs and infrastructure. Such downsizing should be as transparent as possible and should be conducted within a well-defined NARI strategic plan. It is critical that research managers are in agreement from the highest levels that budget savings from downsizing and consolidation will be retained by the research institute to improve operating budgets and salaries of remaining staff.

Strengthening Research Management

Systematic research priority setting and monitoring and evaluation of research programs are important elements in good research management. In contrast with past emphasis on one-off development of research master plans with outside technical assistance, future emphasis should be on developing analytical capacity within the research system to undertake research priority setting and research policy analysis, together with strong commitment by research managers to ensure that research resources shift in ways consistent with identified priorities. The processes for priority setting are as important as the analytical methods used, especially the use of participatory processes that involve a wide cross section of scientists, and the main stakeholders — policymakers, research partners, and clients.

Effective monitoring and evaluation (M&E) of agricultural research programs and projects requires simple nonbureaucratic systems that provide timely feedback to research managers. Monitoring and Evaluation (M&E) should be implemented in a highly decentralized manner, although in large organizations, a
very small central unit can be established to promote M&E, provide training, and develop standards.

**Continuing Effort on Human Resources Development**

The quality of agricultural research is only as good as the quality of the scientific human resource base. This implies continuing effort to re-vamp performance appraisal and promotion systems, train research managers, decentralize project management and budgets to individual scientists, and provide funding for sabbaticals, external travel and greater interaction with the international scientific community. Special attention is needed to mentor the professional development of young scientists. Training will continue to be a priority for NARIs for replacement staff and for upgrading skills to enable researchers to stay current in their disciplines and in emerging fields such as biotechnology, communications technologies, and systems modeling. The further development of in-country (or regional) postgraduate training capacities will be essential to system sustainability.

**Forging Stronger Links with Clients**

All public sector organizations must develop strong linkages with other research organizations, technology transfer institutions, and especially with their clients. Research institutions must be increasingly demand-driven through the involvement of farmers in setting the research agenda and in research financing. Farmers and farmers' organizations will take increasing responsibility for on-farm adaptive research. The clientele of research organizations will also become more diverse with a growing role for agribusiness and consumers in setting the research agenda. Finally research-extension links need to be broadened to include other mechanisms for technology transfer and information dissemination and feedback through farmer organizations, diverse types of NGOs, and the private sector.

**Role of the Bank to 2000 and Beyond**

Since 1981 support to NARSs has been a priority in the Bank's lending portfolio. The Bank has financed 458 projects with agricultural research components in 91 countries, providing a total of $3.9 billion for support to research. Development and dissemination of improved agricultural technologies is central to agricultural and rural development strategies and will be critical to meeting the challenge laid out in the Bank's action plan for the rural sector. Thus it is vitally important that the Bank maintain its strong commitment to the development of national agricultural research systems. The focus on strengthening national research systems and the rapidly changing environment in which those systems operate, have a number of implications for Bank support to agricultural research.

**Policy Dialogue on National Agricultural Research System Strategies**

Creating and maintaining policy dialogue with borrowers on constraints, opportunities, and strategies for national agricultural research systems and sustainable funding, based on economic and sector work, including the country assistance strategy, will be a key part of efforts to strengthen NARS. This process must be highly participatory to build borrower consensus on feasible policy options and institutional reforms, and a policy environment conducive to private-sector investment in R&D and technology transfer.

**Changing Priorities for Project Lending**

Project lending will shift in accord with the new priorities and will likely include the following elements:

- Supporting policy and institutional reforms to improve the efficiency and effectiveness of public research institutes
- Building mechanisms for sustainable funding, including cost recovery programs, farmer financing, joint ventures,
and establishing research foundations and research corporations
- Providing and maintaining critical equipment and materials, investing in scientific information systems, and providing training and technical assistance in new research areas (for example, biotechnology)
- Increasing investments in universities to support both research and the upgrading of educational quality in the agricultural sciences
- Supporting programs to facilitate regional and international collaboration and staff exchanges, and technology spill-ins
- Supporting the development of farmer organizations and mechanisms by which they can influence the research agenda, including participation in cost-sharing arrangements to fund agreed-on research priorities.

Supporting Priority Research Areas

Future projects will also support changing research priorities. A first priority in most project lending will be to support shifts in research paradigms toward sustainable intensification of agricultural systems in both favored and less-favored areas. This will require support to both strategic and applied research on knowledge-intensive practices, such as integrated pest and nutrient and water management to promote input efficiency. Sustainable intensification will also require more emphasis on natural resources management research, including organizational forms for conducting the research, developing links with new sets of stakeholders, and initiating research on associated institutional and policy issues.

Biotechnology research will also be a priority for support. This should include support to the establishment of strategies, policies and associated public safety and intellectual property rights issues to promote biotechnology research, as well as development of external linkages with advanced research centers and the private sector to gain access to the technology.

Finally, in almost all NARS there is a need to strengthen social-science research, which is central to the new priority research areas and to improved research management.

Emphasis on Quality and Knowledge Management

These changes imply that future Bank projects in agricultural research will probably be smaller, but more complex as well as knowledge- and management-intensive in preparation and supervision. Thus a decrease in project size (and possibly lending volume) will not likely be accompanied by a decrease in Bank staff input. Many activities that stress institutional change will have to be piloted before expansion. Developing partnerships with other donors will be an important part of a strategy to bring increased technical and research management skills to project preparation and supervision.

The synthesis and application of good practice in agricultural research will require continuing dialogue within the Bank and with country partners to identify practices most appropriate to a given country situation. Given the rapid evolution of good practice in support to agricultural research, the Bank must be in a strong position internally and through partnerships, to evaluate and synthesize ongoing experiences with new initiatives, such as competitive grants, autonomous research corporations and foundations, farmer financing, joint ventures with the private sector, and links to NGOs. The formation of Bank networks and families can provide a vehicle for both synthesis and dissemination of good practice, including arrangements for systematically tracking change and monitoring new developments. The dissemination of good practice within and across NARSs through case studies, seminars, and study tours, should be a priority in building borrower commitment to institutional and policy changes, and contributing to a global knowledge base on agricultural research policy.
Introduction and Objectives

Investment by both governments and donors in agricultural research in developing countries grew rapidly from about 1970. This was in part stimulated by the successes of the Green Revolution, in which broad-based technical change in agriculture was becoming ever more apparent as an engine of overall economic growth. At the same time, the high returns to investment in agricultural research were noted in the writings of influential economists such as Schultz (1964) and Hayami and Ruttan (1975). Overall, investment in agricultural research in developing countries grew at 6 percent annually from 1961 to 1985 (Anderson, Pardey, and Roseboom 1994).

Then, in the mid-1980s, rapid growth in national agricultural research systems (NARSs) began to slow. From 1981 to 1991 the growth rate of public research expenditures in developing countries slowed to 3.8 percent per year (Alston, Pardey, and Roseboom 1997). Since 1985 there has been a sharp drop in funding in many countries, especially in Latin America and Africa. Meanwhile, the size of research systems, measured by the number of scientists, continued to expand, resulting in reduced expenditures per scientist and a critical shortage of operating funds for research.

The World Bank has provided substantial support for the growth of NARSs. Since 1981 the Bank has lent nearly $3.9 billion for agricultural research through specialized agricultural research loans and loans for broader development projects in which agricultural research was a component. The emphasis in these projects can be broadly classified into three periods:

1. A period of expansion up to the early 1980s—the “bricks and mortar” phase—when the main emphasis was on increasing the size of public-sector research organizations through investment in experiment station and laboratory infrastructure, equipment, and human resource development.

2. A period of transition from the mid-1980s when more emphasis was placed on improving the management of existing research resources in the public-sector research institutes through better planning, improved financial management, greater accountability, and attention to increasing the relevance of the research program to its immediate clients, the farmers. However, as in the first period, most resources in project loans for agricultural research were provided for further expansion and rehabilitation of research infrastructure.

3. The period from the mid-1990s when Bank projects began to emphasize measures to enhance the institutional sustainability of agricultural research systems, defined to include all actual and potential participants in the technology-generation process, such as universities, the private sector, research foundations, and some rural-based NGOs, as well as the governmental national agricultural research systems.
research institutes (NARIs) targeted earlier. In this period, there has been little emphasis on system expansion: in many cases the Bank has supported downsizing and consolidation of public research institutions. Emphasis has now moved from expanding the NARIs toward building a more diverse NARS that incorporates a range of institutional options for conducting agricultural research and development (R&D) and a diversity of funding mechanisms that foster competition and improved articulation among the various participants in the expanded system (McMahon 1992; Echeverria and others 1996). These recent developments represent a sharp departure from the agricultural research policy approved by the Bank in 1980 (World Bank 1980). They also increasingly recognize that the appropriate focus is the "agricultural knowledge system" or "technology innovation system," terms which explicitly recognize that extension and educational systems and user involvement are associated with effective research institutions.

Over the past two decades the environment for agricultural research has changed in other ways as well, especially with the introduction of policy reforms and more liberalized trade in the 1980s. Some of these reforms have promoted private sector participation in R&D. However, the structural adjustment process, which stimulated institutional reform in many public sector enterprises, hardly touched the public sector NARIs, except through reduced budget allocations, which accompanied the general trimming of government budget deficits.

It is appropriate now to examine agricultural research policy in light of the evolving demands on research systems and the potential to introduce substantial efficiency gains in these systems through policy and institutional reforms. Such reforms will be critical to addressing the global problems of food security, poverty alleviation, and conservation of natural resources as highlighted in the 1996 World Food Summit (FAO 1996). Food production in developing countries will have to almost double by 2025, and much of this increase will have to come from biological yield increases in developing countries (McCalla 1994). Sustainable development of agricultural research systems will be central to current World Bank efforts to revitalize agriculture and rural development over the next decade.

The primary purpose of this paper is to discuss key strategic issues in the sustainable development of NARSs and to identify, where possible, "good practices" in agricultural research policy. The paper (1) provides a review of recent changes in NARSs capacity and performance (chapter 1), (2) examines organizational and conceptual challenges in moving from a focus on public research institutes (NARIs) to a focus on research systems (NARSs) (chapter 2), (3) examines key funding and institutional issues facing public sector research programs (chapter 3), and (4) discusses implications for the World Bank for dealing with these emerging issues (chapter 4). We recognize that the issues are necessarily discussed in summary form and cover only selected aspects of agricultural research policy. Despite many commonalities in NARSs problems and their potential solutions, there is no single model of institutional development for NARSs. Best practices are country- and time-specific. Accordingly, we identify some general principles for designing best practices and identify situations under which specific practices may apply.
CHAPTER 1

Recent Evolution of National Agricultural Research Systems

National agricultural research systems are facing a range of new challenges that will shape their future development. Though investment in national systems is substantial and this investment has generally provided good returns, the NARSs are now confronted by a more complex and demanding research agenda and must deal with second-generation issues in institutional development.

Investment in National Agricultural Research Systems

From Pardey, Roseboom, and Anderson (1991), Alston, Pardey, and Roseboom (1997), and others, a number of broad quantitative generalizations can be made about investment in public-sector agricultural research systems in developing countries over the past three decades:

- By the 1980s more than 80,000 agricultural researchers were working in the NARSs of the developing world (table 1.1). (Recent estimates put the number of researchers in developing countries at well over 100,000). During the period 1961–85 the average size of a developing country NARS increased from 155 to 630 full time equivalent researchers.
- By 1991 developing countries were investing US$8,000 million annually in public agricultural research, a level 15 percent higher than the comparable aggregate investment in industrialized countries (table 1.2). In contrast, in 1971 developing country investment in agricultural research was only 70 percent of that of developed countries. From 1981 to 1991 the annual rate of growth in research expenditures for developing countries (3.8 percent) continued to exceed that of developed countries (1.7 percent) (table 1.2).
- By the late 1980s the period of rapid expansion of NARSs was ending and a slowdown in spending on research had become a worldwide phenomenon (table 1.2). The most severe effects were felt in Latin America, Sub-Saharan Africa, and the former Soviet Union. The least affected were the Asian NARSs where research expenditures continued to expand rapidly. Almost everywhere the number of scientists expanded more rapidly than total research expenditures, resulting in a declining expenditure per researcher. This is reflected in reduced operating budgets and in lower real salaries for scientists.
- There is wide diversity across countries in the size and maturity of NARSs. China and India have the largest research systems in the developing world, with tens of thousands of scientists, and account for more
than half of developing country research capacity. But 95 of 130 NARSs in developing countries still employ fewer than 200 researchers, and 39 systems employ fewer than 25 researchers.

- The intensity of investment by the public sector in research in developing countries, measured as a share of agricultural gross domestic product, is about 0.5 percent (table 1.3). Although this has risen from 0.38 in the early 1970s, it is relatively low and has remained nearly unchanged since the late 1970s. This is far below the two percent target recommended by the World Bank (1981) and the average for industrialized countries of 2.39 percent (Alston, Pardey, and Roseboom 1997).

- The intensity of research investment is generally lower for large NARSs and for major food crops, such as rice and wheat, reflecting economies of size and scope in conducting many types of research (Byerlee and Traxler 1996). Lack of these economies of size and scope presents special problems for small NARSs.

- The quality of scientific manpower, as measured by the proportion of scientists with postgraduate degrees, has increased sharply in all countries, and especially in Sub-Saharan Africa, which had very few trained scientists in the 1960s. Currently more than half of the agricultural researchers in developing countries hold a postgraduate research degree. In spite of

Table 1.1  Number of scientists employed by the public sector of national agricultural research systems

<table>
<thead>
<tr>
<th>Region</th>
<th>Agricultural research personnel (full-time equivalents)</th>
<th>Growth rate (percent per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developing countries (130)a</td>
<td>20,256</td>
<td>37,221</td>
</tr>
<tr>
<td>Sub-Saharan Africa (43)a</td>
<td>1,323</td>
<td>2,416</td>
</tr>
<tr>
<td>China</td>
<td>7,459</td>
<td>11,781</td>
</tr>
<tr>
<td>Asia and the Pacific (28)a</td>
<td>6,641</td>
<td>12,439</td>
</tr>
<tr>
<td>Latin America and the Caribbean (38)a</td>
<td>2,866</td>
<td>5,840</td>
</tr>
<tr>
<td>West Asia and North Africa (20)a</td>
<td>2,157</td>
<td>4,746</td>
</tr>
<tr>
<td>Industrial countries (22)a</td>
<td>40,395</td>
<td>48,123</td>
</tr>
<tr>
<td>Total (152)a</td>
<td>60,651</td>
<td>85,344</td>
</tr>
</tbody>
</table>

a. Bracketed figures indicate the number of countries in the regional totals.

Note: The growth rate represents the compound annual average growth rate between 1961–65 and 1981–85.


Table 1.2  Public agricultural research expenditures: Global trends

<table>
<thead>
<tr>
<th>Region</th>
<th>Expenditures (millions of 1985 international dollars)</th>
<th>Annual growth rates (percent per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developing countries</td>
<td>2,985</td>
<td>5,535</td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td>699</td>
<td>927</td>
</tr>
<tr>
<td>China</td>
<td>457</td>
<td>934</td>
</tr>
<tr>
<td>Asia and the Pacific (excl. China)</td>
<td>862</td>
<td>1,922</td>
</tr>
<tr>
<td>Latin America and the Caribbean</td>
<td>508</td>
<td>1,008</td>
</tr>
<tr>
<td>West Asia and North Africa</td>
<td>459</td>
<td>738</td>
</tr>
<tr>
<td>Industrial countries</td>
<td>4,238</td>
<td>5,713</td>
</tr>
<tr>
<td>Totala</td>
<td>7,283</td>
<td>11,248</td>
</tr>
</tbody>
</table>

a. The total excludes Cuba and the Russian Federation.

this, research systems in many countries have difficulty recruiting or retaining qualified staff.

- In recent years private sector investment in agricultural research has increased rapidly. Currently the private sector accounts for 10-15 percent of resources invested in developing countries (Bonte-Friedheim, Tabor, and Roseboom 1994; Pray and Umali-Deininger 1997), compared to 50 percent in industrial countries. Much of this research is located in Latin America and Asia, where it is concentrated in a few large countries, such as Brazil, Mexico, Argentina, and India. The bulk of private research is performed by local and multinational companies engaged in farm-input supply industries (for example, seeds, fertilizers, pesticides, and machinery) with some research occurring in the food processing sector (James 1996).

### Payoffs to Research Investments

On the output side there is little doubt that agricultural research has made important contributions to overall productivity growth. Yields of most major crops in the developing world (with the important exception of Sub-Saharan Africa) have shown unprecedented rapid growth in the past three decades and yield growth rather than area expansion has now become the major contributor to increased agricultural production. The evidence suggests that total factor productivity (TFP) in developing countries has grown at 1-2 percent per year—only slightly less than in industrialized countries—and that research accounts for one-third to one-half of that growth (Pingali and Heisey 1996). There is some evidence, however, that TFP growth has been slower in the post-Green Revolution period (Morris and Byerlee forthcoming). This may indicate diminishing returns to Green Revolution strategies of technical change and of emerging problems with sustaining the quality of the resource base.

Studies have found a high rate of return to investments in research in developing countries (see Echeverría 1990 and Evenson and Rosegrant 1993 for a review of more than 100 such studies). While there are always questions about the scope and methods of these studies, there is little doubt that investment in agricultural research has, on aggregate, been a huge success. Even in Sub-Saharan Africa, where yield increases from new technologies have been relatively modest, studies indicate that research has paid off (Oehmke and Crawford 1996). Rates of return may, however, have fallen in recent years, as marginal gains from some types of research have declined in the post-Green Revolution period (Lipton 1994; Byerlee and Traxler 1995). In crop research, much of the benefit to date has been generated through varietal development (box 1.1). Despite the increasing importance of improved crop and resource management for sustainable

### Table 1.3 Intensity of public sector investment in agricultural research

<table>
<thead>
<tr>
<th></th>
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<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Developing countries</td>
<td>0.38</td>
<td>0.47</td>
<td>0.50</td>
<td>0.49</td>
<td>0.51</td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td>0.78</td>
<td>0.84</td>
<td>0.86</td>
<td>0.74</td>
<td>0.70</td>
</tr>
<tr>
<td>China</td>
<td>0.40</td>
<td>0.48</td>
<td>0.41</td>
<td>0.38</td>
<td>0.36</td>
</tr>
<tr>
<td>Asia and the Pacific</td>
<td>0.26</td>
<td>0.36</td>
<td>0.44</td>
<td>0.50</td>
<td>0.55</td>
</tr>
<tr>
<td>Latin America</td>
<td>0.43</td>
<td>0.51</td>
<td>0.59</td>
<td>0.49</td>
<td>0.54</td>
</tr>
<tr>
<td>West Asia and North Africa</td>
<td>0.50</td>
<td>0.49</td>
<td>0.52</td>
<td>0.52</td>
<td>0.52</td>
</tr>
<tr>
<td>Industrial countries</td>
<td>1.38</td>
<td>1.60</td>
<td>1.98</td>
<td>2.18</td>
<td>2.39</td>
</tr>
<tr>
<td>Totala</td>
<td>0.67</td>
<td>0.76</td>
<td>0.81</td>
<td>0.79</td>
<td>0.81</td>
</tr>
</tbody>
</table>

a. The total excludes Cuba and the Russian Federation.
Strengthening National Agricultural Research Systems

Box 1.1 Crop improvement research: An institutionalized success story

Plant breeding has been the major success story of agricultural research in developing countries over the past three decades. These successes now go well beyond the widely documented cases of development and adoption of modern varieties of rice and wheat in irrigated areas.¹

More than 70 percent of the cereal area in the developing world is now sown to so-called modern varieties (Byerlee 1996). The remaining areas covered by traditional varieties are usually in more marginal areas, although there is still considerable scope for adoption of modern varieties in medium- and high-potential areas in Sub-Saharan Africa. Since the spread of the first semi-dwarf rice and wheat varieties in the 1960s, at least two generations of new varieties have been adopted in most areas of Asia and in commercial agricultural areas of Latin America. These successive generations have provided important benefits in higher and more stable yields.

The success of genetic improvement research can be attributed to local innovations, international agricultural research center (IARC) support, and long-term political and institutional commitment to food-crop research. The IARCs have provided strategic support to national breeding programs through the supply of advanced genetic materials, often with specific traits, such as pest resistance, which require intensive breeding efforts. One-half or more of the varieties released in developing countries are based directly or indirectly on IARC-linked germplasm.

The success of genetic contributions to productivity growth also reflects the high priority that NARSs placed on developing strong crop-breeding programs. The number of scientists engaged in crop breeding has increased rapidly. By 1990, the intensity of investment in crop breeding in developing countries, measured by the number of scientists per unit of production, was as high as in industrialized countries (Bohn and Byerlee 1993). Institutional innovations in the form of nationally coordinated commodity research programs have provided an integrated approach to highly focused crop-improvement work. This has enabled NARSs to capture within country "spill-ins" of varieties and germplasm developed in other regions or states within a country.

1. Much of this box is based on Byerlee and Pingali 1995.

productivity improvement, research in this area has generated few successes (box 1.2).¹ In the 1990s NARSs are being challenged to maintain the productivity of successful research programs (such as crop breeding), revamp or drop unproductive research areas, and respond to new research challenges, all within the context of ever tighter research budgets.

The Changing Agricultural Research Agenda

In recent years the economic and technical environment for research has changed drastically. Three major changes have far-reaching implications for the NARSs. First, trade liberalization has shifted economic incentives toward activities in which countries have comparative advantage. Some traditional crops are now exposed to competition from imports and may no longer be profitable (for example, maize in much of hillside Mexico and Central America), while liberalization has opened opportunities for nontraditional crops, especially high-value export crops (for example, cut flowers and horticultural products). Improved technology is a critical factor in a country's ability to exploit its comparative and competitive advantages (Bathrick and others 1996).

Second, agricultural research will be even more important in increasing productivity in the future than it has in the recent past. In the course of agricultural development, technical change generally provides an increasing share of output growth, relative to resource-based strategies (for example, expanded land area and investment in irrigation), and input intensification. In contrast with the past three decades, when the major emphasis was on intensification of input use and cropping patterns, the next stage of productivity increases will depend on pushing the production frontier outwards, increasing the efficiency of input use, and sustaining the resource base. These research activities are more knowledge- and skill-intensive, since scientific knowledge embodied in new seeds (for example, a pest-resistant variety) or in the form of improved
Box 1.2 Crop and resource management research: A continuing challenge

Research on crop and resource management has not had the expected impacts. Most crop-management research has focused on input intensification, especially the use of external inputs to exploit the yield potential of the new varieties. However, other factors, such as the adoption of modern varieties and the development of more effective input markets, have probably been more influential than crop management research in fostering higher levels of input use.

Crop-management research has been slow to enhance the efficiency of input use and more sustainable production systems. One of the few success stories demonstrating the potential of this type of research is the adoption of integrated pest management practices on rice in some countries in Asia. For example, between 1987 and 1990, the introduction of an IPM program on rice in Indonesia resulted in a 50 percent decrease in use of pesticides, a 15 percent increase in yields, an increased net profit per farmer a season of US$18, and a government savings of US$120 million a year in pesticide subsidies (Schilhorn van Veen and others 1997).

In high-potential areas, the importance of emphasizing more efficient use of inputs is reinforced by heightened concern about sustaining the quality of the resource base, especially for intensive production systems, where input use is already high (Cassman and Pingali 1995). There are unlikely to be quick “technological fixes” for natural resource degradation. For the immediate term at least, increasing productivity (and maintaining past productivity gains) is likely to come from incremental gains from a wide array of management practices, rather than any one technological breakthrough. While individually less newsworthy than the Green Revolution technologies of the past, these sources of growth, taken together, will nevertheless be significant.

In low-potential areas, a “plant breeding first” strategy has generally failed, and it is now widely agreed that improvements in crop and resource management offer the best scope for increasing productivity and conserving the natural resource base (for example, Janssen 1993). There are few documented success stories attributable to the adoption of improved crop management technologies in marginal areas. Adoption of such practices often requires changes in local institutions (for example, land-tenure security) and policies (for example, removal of input subsidies).

Byerlee and Eicher 1997 for the case of maize), these have been relatively localized, dependent on one technology such as hybrid maize, and have not resulted in sustainable long-run growth. The development of agricultural knowledge systems to respond to the urgent need to increase food production in the diverse and risk-prone agroclimatic environments of Africa must be a high priority for the development community into the twenty-first century.

Finally, there are important changes in the technology for research itself, especially in the new biotechnologies and informational technologies. Institutionally, the new biotechnologies raise important issues for research systems due to the considerable size economies of much of the research and the fact that the private sector in industrialized countries dominates the applied end of this type of research. Several large countries (for example, India) have moved aggressively to establish centers of excellence in biotechnology, and the IARCs are

1. Much of this box is based on Byerlee and Pingali 1995.
Strengthening National Agricultural Research Systems

also shifting resources toward biotechnology, although their levels of investment may not yet be adequate. New information technologies (such as crop modeling, geographic information systems, remote sensing) will be important research tools and will have important implications for research organization and linkages. New communication technologies will sharply reduce the cost of communication among scientists in the same NARS or internationally, and these new technologies may reduce economies of scale and the critical mass needed for some types of research. The new technologies may also help close the knowledge gap between scientists in developing and industrialized countries.

Emerging Institutional Challenges in National Agricultural Research Systems

The increasing demands being placed on research systems contrast starkly with the lack of institutional innovation in research-system management and organization and the stagnation or decline in funding for agricultural research. Unstable research funding makes it difficult for national and international research programs to commit human and financial resources to address the long-term strategic issues crucial for sustaining productivity growth. With few notable exceptions, such as the Punjab of India, the public research systems that will continue to be the key source of technical change for basic food staples have failed to muster political support for funding agricultural research.

Reform of public research system organization and management is long overdue. The 1970s and early 1980s were golden years for agricultural research. Agricultural research was a prestige investment and, with rapidly rising budgets, research programs and institutes proliferated. The relative abundance of resources flowing to NARIs led to complacency in research management and lack of demand for accountability of management to those who financed research. In the austere budgetary climate of the 1990s, it is clear that there are considerable potential efficiency gains in NARIs from streamlining research priorities, reforming management and incentive systems, and involving a broader range of institutions in the research process.

Concerns also arise about the relevance of current institutional structures and governance. The issue now is whether the highly centralized research management that characterizes many NARIs is the appropriate organizational mode. There are also questions about the future of semiautonomous national research councils. These were established to coordinate the financing of research and to give agricultural researchers independence from the “tyranny of civil-service regulations” on hiring and remuneration (Antholt 1994). In practice, few have been able or willing to break away from the rigidities of government civil-service rules. Consequently, many research systems are suffering a crisis of management, with top-heavy bureaucracy, centralization of decisionmaking, and lack of incentives for the innovation process so essential for research (Antholt 1994; McIntire 1994). Although these problems are generic, situations vary considerably and require country-specific analysis (box 1.3).

As a result of these problems and the difficulties in making the transition from a culture of program expansion (building, training, gearing up) to that of production (of ideas, research papers, and extension recommendations), most NARIs have failed to develop the science environment needed to spur innovation and discovery and which largely determines effectiveness. One result is a decline in the quality of scientific output, since it has become difficult to attract and retain the best scientists in public sector agricultural research (Purcell 1994). Few NARSs have adequately bridged the gap between public research suppliers and technology users. The public-good nature of research has not been adequately defined and the private sector and farmers have not been sufficiently integrated into the technology systems—either as financiers of research or as partners in the conduct of research.
In summary, the substantial investment in NARIs over the past two decades has not yet resulted in the institutional capacity and output expected. A major human and physical infrastructure is now in place, but many NARIs that developed rapidly have suffered erosion of capacity over the past decade because of uncertain funding, lack of articulation with other actors in the NARSs, lack of transparent long-run strategies and priority-setting mechanisms, and difficulties in maintaining the quality of human resources (McMahon 1992; Purcell and Anderson 1997).

Notes

1. Less is known about the impacts of livestock research. Undoubtedly the major impact of livestock research has been in livestock health. Livestock nutrition research appears to have provided few benefits, despite considerable activity (Corneilus de Haan, World Bank, personal communication).

2. Since high investment costs are required to establish biotechnology research capacity, initial research projects are costly, but additional research projects can be added with relatively little additional investment in facilities.
CHAPTER 2

National Research System Development: Issues and Good Practice

The paper now reviews selected key issues facing research managers, policymakers, and the Bank in positioning national research systems to address challenges into the twenty-first century. We divide these into the major issues for the evolving NARSs (discussed here in chapter 2) and key challenges for the public sector research institutes (that is, the NARIs) within those NARSs (discussed in chapter 3).

An important change in the 1990s has been to move beyond equating the national agricultural research system with the public research institute (NARI) to viewing it as institutionally pluralistic system that includes:

- Universities, which often command access to well-trained human resources, but which have often been considered as solely teaching institutions
- Private companies, which seek to develop and sell technological products for profit
- Agricultural research foundations, which enjoy varying degrees of private and public support
- Farmer organizations and cooperatives, which might organize their own research institutions or support research by other means
- NGOs, some of which have the capacity to undertake certain types of research, especially adaptive research.

With the swing toward privatization, decentralization, and competitiveness in the late 1980s and 1990s, the public sector monopoly of the NARI is now an obsolete institutional model for building NARS capacity (Echeverría, Trigo, and Byerlee 1996). The challenge for most countries is determining how to capture the potential of alternative suppliers to bring more resources into the formal research system, and identifying how to exploit the complementarities among various participants to develop a well-articulated research system. This requires that NARS institutions, public or private, develop strategic linkages with other private and public sector R&D efforts at the regional and global level. Such changes bring increased institutional complexity and require significant institutional innovation. The major challenge for the NARSs is, therefore, how to involve and link these various actors at the national and international levels to meet national objectives for the agricultural and rural sectors.

Conceptual Overview of the Emerging National Agricultural Research Systems

The conceptual view of national agricultural research systems has evolved, and continues to evolve rapidly. Prior to 1960 most agricultural research was carried out in government
departments and experiment stations that were not integrated into a coordinated national system. Beginning in the 1950s many developing countries formalized public sector involvement in agricultural research with the formation of national agricultural research institutes, which grew rapidly in the period of rapid expansion of funding for agricultural research through the 1970s. In this period a national research system (that is, the NARS) was viewed largely as a linear system with the ministry of agriculture providing funds to a national agricultural research institute, which developed new technologies that were passed to extension for dissemination to farmers (figure 2.1). In this view, private sector R&D, if it was recognized at all, was seen as being something apart, largely associated with supply of certain inputs to commercial farming where the benefits of investment in R&D could be appropriated (for example, hybrid seed, machinery, and agricultural chemicals).

The emerging view of NARSs in the 1990s differs from this traditional view in several respects (figure 2.2). First, it distinguishes between the funding of research and the execution of research as separate functions requiring different skills and inputs. Research funding and the setting of broad priorities for research are policy tasks that relate to policy objectives and client needs. Once funding levels and research priorities have been established research execution by alternative suppliers becomes an efficiency issue (Echeverria, Trigo, and Byerlee 1996). While funding and execution may continue to be under the same organization, there is a strong case for separating them institutionally. A separate funding body can use competitive grants to seek the most efficient research providers for a given research product, avoid conflicts of interest in awarding research contracts by not itself conducting research, and oversee the quality control of research through setting research standards and organizing external reviews (box 2.1).

Second, the new concept of a NARS recognizes the importance of diversity in the funding and execution of research (McMahon 1992).
Box 2.1 Funding versus execution of research in Australia

One model that clearly distinguishes research funding and priority setting from research execution is that of the research and development corporations in Australia. These corporations were set up as semi-autonomous bodies as a partnership between government and farmers, with funding provided equally by each partner. The sixteen research corporations, representing most major commodities as well as research on land and water management, are each governed by a board with representation from government, farmers, agribusiness, scientists, and the wider community. The corporations operate with small staffs and low administrative costs (less than five percent of total research funds), set strategies and priorities, and allocate funds, mostly through competitive bidding. The corporations have full autonomy to contract research to public and private sector institutes, including foreign institutions.

Instead of funding being solely dependent on the government treasury, a variety of means of funding research are exploited, including private sector and farmer contributions. Even in the public sector, funding may be diversified from the ministry of agriculture to other ministries, such as science and technology and environment. This diversification of funding sources can potentially increase funds for research and at the same time stabilize funding levels, since the risk of sole dependence on one source is reduced. Likewise, various public and private institutional forms, especially universities and various types of NGOs, including foundations, may be used to execute research. The participation of other actors in research execution allows the human resources and skills available for research to be increased (for example, by tapping underused skills in universities) and efficiency to be enhanced by matching scientific skills with needs. Reorienting thinking so that a NARS is viewed as a collection of institutions and programs rather than a monolithic NARI will remain a challenge to development practitioners and research program leaders. However, various forces that combine to make the pluralistic NARS a reality include budgetary pressures on research agencies, greater scientific capabilities within a range of institutions, increased client and stakeholder pressures on institutions, greater sophistication of institutional structures, and changing research agendas.

Third, in the new view of NARSs, the private sector is recognized as a full player in the development and dissemination of agricultural technology: the public sector is focused more sharply on public goods (Umali 1992). In research, public goods are characterized by technologies where it is impossible or very costly for private firms to appropriate all the benefits of investment in R&D, since it is not possible to exclude potential users once a research product becomes available. In addition, public sector intervention in agricultural research is often desirable for other reasons (Alston, Pardey, and Roseboom 1997):

- High fixed costs and uncertain, long-term payoffs to research that make it unprofitable for individual small firms (that is, farms) to conduct research
- Positive or negative environmental externalities of much agricultural technology (for example, soil conservation, agroforestry, and pesticide use).

For these reasons there is a strong case for public sector involvement in basic and strategic research (long-term research with uncertain payoffs and high spillovers), research on problems of small-farm agriculture (high costs of collective action for organizing their own research), and research on natural resource management (positive environmental externalities). However, the role of the public sector continues to evolve with changes in technology and institutions. For example, with emphasis on biotechnology and with new forms of intellectual property protection for biological products and processes, the private sector is now a major player in basic and strategic biological research that was previously almost exclusively in the public sector.

Fourth, despite the sharper delineation of the public and private sector roles in funding research, there are often efficiencies in private-
public collaboration in both the funding and execution of research due to the complementary skills and resources in each sector. The private sector may find it efficient to contract the provision of research to public research institutes that have specialized research infrastructure and skills: public research institutes may find it valuable to collaborate with private sector firms that have appropriate business contacts and experience in commercialization of research products (figure 2.2).

Fifth, for public sector research institutes to operate effectively in this new environment, they require increased flexibility in financial and human resource management—for example, autonomy to engage in contracts with private firms, or to engage specialized skills. This implies that public sector research institutes must seek new institutional models that provide some level of autonomy from traditional civil service models.

Sixth, and critically important, stakeholders, especially the clients of the research system, have an increased role in research priority setting and implementation to ensure that research is driven by user demands. The institutional models for achieving this may range from full or partial funding of research by stakeholders to involvement of farmers in the governance of research funding and executing bodies, and to farmers’ organizations contracting research organizations to execute adaptive research.

Implicit in the increased importance of stakeholders is the need for institutions within the NARSs to become more responsive to the needs of the stakeholders and to become accountable for producing results. Research agendas will be less shaped by national planning and national policies and more by the requirements of markets (domestic and export) and the country’s comparative and competitive advantages. Private sector financiers of research in the public sector necessarily demand accountability and results (profits) from their investments. Public funding agencies facing difficult choices among alternative investments and ever scarcer public resources are looking for research institutions to become more "results-oriented."

Finally, the traditional research-extension link will be less relevant, since much research will be done with the direct involvement of potential technology users as financiers and executors of research. In addition, technology dissemination and information transfer programs are undergoing a similar transformation with a conceptual distinction between funding and execution of technology dissemination activities and with a greater diversity of providers of extension services. These service providers are forced to be more accountable and active in developing linkages to sources of new technology. Effective research organizations will need to develop new models of technology transfer that involve formal and informal partnerships with a variety of providers of extension and information dissemination services.

Coordination in the Emerging National Agricultural Research Systems

The complexity of the new NARSs raises the issue of how to coordinate research to meet national development objectives. There cannot, and probably should not, be a complete coordination or integration of various research programs: institutional mandates, objectives, and interests will naturally diverge. Private sector research frequently requires some degree of secrecy and independence because of the profit motive. University research may (but need not) be directed toward more ad hoc and academic research activities. Stakeholder interests may conflict (that is, small-scale producers versus large producers; producers versus consumers). Yet, to meet national objectives, some degree of coordination and integration is needed to link varied programs in a national system that achieves efficiencies through collaborative research activities, networking, sharing of results, and improved allocation of research funds.

Mechanisms for governance of multi-institutional NARSs are not yet well developed. As
NARSs mature and evolve more complex organizational structures, research leaders and policymakers should give explicit attention to establishing systems that enable researchers from various institutions to share information, exploit complementarities between institutions, and avoid duplication of efforts. Many countries have attempted to do this through the formation of apex research councils responsible for:

- Developing national research strategies and plans
- Linking research to broader agricultural policy discussions
- Channeling funds to priority research areas, and thus coordinating research across research institutions, especially in a federal-state system
- Promoting collaboration and exchanges among the various parts of the NARS
- Coordinating external linkages, especially with NARSs of neighboring countries and with donors.

Such a research council, if broadly representative of the clients of research (for example, policymakers and farmers), should provide a national forum for developing research strategies and allocating research funds. However, in practice, many apex research bodies have become large research institutes in themselves with major involvement in research execution. In other cases apex organizations have been charged with research planning and coordination, without control over funds. Both situations typically lead to failure of the organization to undertake its primary responsibilities of directing research policy.

In countries with an apex research council, public funds should be administered by this council, and the council should divest itself of administrative activities in research execution by giving more autonomy to its research institutes. Councils should ensure that producers have input into the process of research planning and evaluation. Where there is no apex research organization, the creation of a small, nonbureaucratic council should be considered. However, the creation of a new institution always runs the danger of adding another layer of bureaucracy to research decision making. Other institutional mechanisms may need to be considered, such as:

- A research coordination committee to allow regular consultation and communication among various NARS participants
- National coordinated research programs and networks in which various institutions collaborate and exchange information for a particular research area
- Research workshops that bring together all interested researchers, clients, and stakeholders for a particular type of research and provide an opportunity to share research results, compare plans, and coordinate future work
- Competitive research grant programs to direct research efforts of various institutions and to promote linkages between different programs
- Professional associations, research journals, annual research reports, newsletters, and other publications that keep scientists throughout a NARS informed of current research efforts and accomplishments.

Each country will have to work out its own specific institutional model for coordination within the NARS. In large countries several models may be needed to represent the interests of different commodities or regions in research funding and priority setting. Finally, it is very useful for a country to develop a broad-based consensus or vision for the future evolution of the NARS (box 2.2). Such a vision or technology policy is the starting point for efforts to reform research systems and increase efficiencies.

**Competitive Funding of Research**

Competitive grants (CGs) can help coordinate research across different institutions in line with national priorities as well as generate efficiencies and stimulate innovation in research programs. Competitive funds can also be used to consolidate funding from different sources to address national priorities.
**Box 2.2 Building consensus: The importance of a strategic vision**

Research investments should be consistent with and supportive of national objectives. Each NARS needs a broad “vision" of the future evolution of the research system over the next 10-20 years that is preferably developed within the framework of a national science and technology policy. This NARS vision should succinctly outline the changing demands for technology, the expected future roles of the public and private sectors and their interaction, the comparative advantage and mandates for central, state, and local research institutes, and the role of universities. The vision should also analyze future sources of funding, new funding mechanisms, and needed changes in the public sector NARI to promote greater efficiency in use of resources, including institutional autonomy and governance and linkages with clients, technology transfer agencies, and the global agricultural research system.

The NARS vision statement can be developed by the apex research body, the NARI, or a specially constituted committee or commission. In each case considerable dialogue among all stakeholders is needed to ensure broad consensus on the future direction of the NARS. Such a vision statement should also be a foundation for Bank support to a new lending program for agricultural research.

CGs are generally advertised, with selection of grants for funding based on a peer-review process with criteria defined by research priorities and scientific merit. Although CGs have been used in many NARSs for many years, these have accounted for only a small proportion of the total research budget.

CGs have a number of potential advantages. They can:

- Allow funds to be channeled to the most productive researchers (as judged by the peer reviewers). They can thus improve the productivity, job satisfaction, and commitment of scientists
- Enhance the quality of research by requiring detailed proposals from scientists and by technical review of the proposals prior to funding
- Draw a wide range of participants into the research system by making competition open to all, including NGOs, universities, and the private sector
- Mobilize established research infrastructure and human resources, which might otherwise be under-used because of shortage of operating funds
- Promote partnerships in research by encouraging collaborative research proposals across institutions, including joint public-private sector research
- Reallocate research resources in the short term by tying grants to high priority research areas and types of research (for example, biotechnology and multidisciplinary research).

Several potential difficulties with CGs that should be recognized:

- Most grants are for a fixed period (usually no more than three years) and are less appropriate for supporting long-term research.
- It is often difficult to establish an independent peer review system in situations in which a research culture is subservient to seniority and administrative hierarchies.
- In small NARSs there may be few potential competitors for funds, so CGs may fail to promote competition. It may also be difficult to find peer reviewers who do not have personal interests in the projects being reviewed.
- The peer review system is inherently conservative and may discount projects outside the currently accepted view of science.
- Administration of CGs may get mired in the normal bureaucracy of government civil service, resulting in long delays and administrative barriers to accessing funds.
- CG systems are generally more costly, since scientists may spend considerable time in writing proposals that are not funded and peer review is a time-consuming and skill-intensive activity.
- CGs usually only fund operating costs and essential equipment. Undue reliance on
CGs may be at the expense of maintaining existing research infrastructure.

CGs have become popular in recent years in many NARSs, but CGs are not a substitute for institutional development and longer-term investments in developing research infrastructure. Successful CG program management requires good monitoring and evaluation systems. In countries with underused research capacity, CGs can be an efficient means for financing research, but CG programs may become less effective over time, if research infrastructure (both human and physical) depreciates and if grant managers and recipients become “entrenched” so that the programs are less competitive.

These characteristics of CGs suggest a number of good practices. CGs are most appropriate in mature and larger NARSs seeking to widen participation in the research process and provide incentives for increasing productivity. In small NARSs (with less than 100 scientists), the high administrative costs and limited potential for competition reduces the value of CGs. CGs should not be the sole mechanism for funding, but should be used to complement funds from regular budget appropriations. CGs are most appropriate to fund new research areas and research and development that requires collaboration, such as public-private partnerships. Long-term research requiring continuity (for example, a plant breeding program) as well as the building and maintenance of research infrastructure are best funded through annual budget appropriations.

The use of CGs should be introduced on a pilot basis to fund selected priority areas and then be evaluated for effectiveness to guide any expansion of the program and to refine procedures and institutional arrangements to administer the CGs. In order to make the process transparent and to widen participation, introduction of a CG system should be accompanied by a detailed manual and appropriate training programs on procedures for soliciting, preparing, and evaluating proposals, criteria for selecting proposals, and guidelines for monitoring and evaluation. Management of a CG scheme should have maximum flexibility and independence from political and bureaucratic interference. Where this is not possible within the public sector, a special board or foundation may be needed to administer the CG.

**Integrating Universities in the NARS**

Despite substantial R&D capacity many universities in developing countries remain on the periphery of agricultural R&D (Rukuni 1996) (box 2.3). This contrasts with some countries (for example, the United States and India) where universities predominate in public sector agricultural research. Universities provide a pool of well-trained scientists with substantial capacity for executing agricultural research. Universities also train the next generation of scientists.

The basic strength of universities is that their research and training functions are complementary to each other since research is an integral part of postgraduate education. Universities frequently have an institutional culture and a relatively autonomous status conducive to research, but difficult to establish within a NARI. The greater flexibility in operating procedures and regulations in universities may make it easier for university scientists to obtain funding and engage in collaborative research with private sector firms and other funding entities. Indeed, in some countries it may be most appropriate to place universities in the lead in executing research and to give them the status, responsibility, and funding usually associated with NARIs.

The move toward looking at research systems as a whole will inevitably elevate the role of universities in research. The following measures can also be used to better integrate universities into NARSs:

- Shift more funding to competitive grants to tap university skills in research.
- Develop collaborative research programs (for example, through a special fund) between NARIs and universities, especially in the common situation where these institutions are physically close.
Box 2.3 Why have universities been underutilized in national agricultural research systems?

For several reasons, universities have often been marginalized from agricultural research:

> Universities are generally administered under ministries of education, which have no mandate for and little interest in promoting agricultural technology.

> Universities have little funding for research. In Nigeria the 53 percent of agricultural scientists in the universities had access to seven percent of the funding for research, while the 47 percent of the scientists in government institutes had access to 93 percent (Hoste and others 1995).

> Universities provide inadequate incentives for research.

> National agricultural research strategies and plans have not recognized the potential role of universities and have not provided mechanisms to link university research into the overall national plan.

> Institutional and sometimes personal rivalries sometimes exist between universities and the ministries of agriculture that oversee both the financing and execution of research.

> In many countries universities are frequently disrupted by political demonstrations, strikes, and shutdown of university operation, a situation incompatible with continuity in research work and prejudicial to sustained government funding.

- Provide opportunities for staff exchanges, such as graduate students undertaking thesis research in the NARI and NARI scientists taking sabbatical leaves in universities.

- Develop interlinkages in governing bodies with representatives of universities sitting on governing boards of NARIs, and vice versa.

- Reduce donor support for foreign postgraduate training and channel this support to developing local university capacity in both undergraduate and postgraduate training. This change may begin with master’s degree programs, followed by general Ph.D. programs (for example, in plant breeding and agronomy).

NARSs must institute policy and structural reforms to expand university roles in research, and universities themselves must adopt policies and develop capabilities to conduct research. In addition, upgrading of universities will be critical to improving the human resource capacity for scientific research in both the public and private sectors of NARIs. Given the high cost of foreign postgraduate training, a sustainable NARS must have capacity to produce most of its replacement scientists.

To ensure NARS development much more effort is needed to establish and support research in the university sector. Larger universities with substantial research may need strategic plans, monitoring systems, and systems for setting priorities. Many must give attention to research management and research policies and will need to address operational issues similar to those in NARIs (see chapter 3). These issues include: providing incentives for research, maintaining and upgrading research facilities, encouraging contract and grant research funded by the private sector and other sources, obtaining intellectual property rights and commercializing some research products and services, and better use of their most valuable asset—relatively low-cost postgraduate students.

### Increasing the Role of the Private Sector

The gap in funding for research in the public sector can partly be alleviated by seeking an increasing role for the private sector. The private sector can invest in its own R&D capacity expecting to earn profits from that investment, or it can mobilize resources for profit or nonprofit goals through private research foundations.

**Investment by the Private Sector in Research and Development**

Although private-sector investment in R&D is increasing in developing countries, it still only accounts for 10–15 percent of total agricultural
R&D expenditures (Bonte-Friedheim, Tabor, and Roseboom 1994; Pray and Umali-Deiniger 1997). Privatization of agricultural research has proceeded most rapidly in Latin America, where the private sector contributes up to 40 percent of the R&D expenditures in some countries (Falconi and Elliott 1995; Echeverría and others 1996). In contrast, private sector agricultural R&D is estimated to account for half of the research expenditures in the industrialized countries (Alston and others 1997).

In developing countries private-sector investment in R&D has been dominant in agricultural chemicals and machinery, where much of the technology has been directly transferred from industrialized countries. Private sector R&D is also growing rapidly in other areas, especially for hybrid seed. In Asia and Latin America private sector R&D in the maize seed industry now probably exceeds that by the public sector. Although the R&D that established the market for hybrid seed has largely been carried out in the public sector, participation of the private sector in R&D increases as the market matures. Since many developing country markets are reaching this phase of development, and given the development of hybrid seed technology for other crops (for example, rice and cotton) and the implementation of plant variety rights, the importance of the private sector in crop improvement R&D will probably increase rapidly.

Private-sector R&D can be promoted by a number of policy and institutional reforms:

- Encouraging private investment in general in the agricultural sector, including foreign investment.
- Removing barriers to private sector participation (including rules on access to public-sector research products) and relaxing rules on approval and release of new technologies (such as new varieties) and on importing technology.
- Strengthening legal structures to allow private appropriation of the benefits of private R&D, including legislation on trade secrets and intellectual property rights (IPR).

These changes are already well under way in many countries and have stimulated private sector R&D. However, private sector R&D in most developing countries will probably be limited for many years for some of the following reasons:

- Many products of research will continue to be public goods that do not attract private sector investment. These include crop, livestock, and resource management practices, where the major product of research is information (for example, IPM).
- Even with implementation of IPRs, private sector research will focus on commercial agriculture. For example, in plant-breeding research, it is difficult to see how it will be cost-effective for private firms to enforce IPRs for self-pollinated crops in the small-holder sector, where seed can easily be passed from farmer to farmer.
- Developing private R&D is a long-term process, which requires considerable input from public R&D. Even proprietary hybrids are often based on prebreeding and breeding research in the public sector. The main source of scientific personnel for private-sector R&D efforts is the public sector NARI.
- Market size is an important determinant of private R&D. This places small countries and secondary commodities at a disadvantage in attracting private R&D. Since most countries still restrict technology imports (by varietal release procedures and regulations on imported seed), private R&D in small countries will only prosper where countries within a region adopt open-border policies for technology flows, so that private companies can target a region rather than a single country.

These comments point to the complementarities of public and private sector R&D. However, too often the public sector has viewed the private sector as a competitor. A much more constructive approach would develop strategies to exploit complementarities. These strategies could include:

- Backing private sector R&D with strategic and applied research in the public sector in
ways that foster a competitive and efficient private sector, including the development of R&D capacity in local agricultural input-supply firms.

- Focusing public sector research in areas unlikely to attract the private sector, because of the nature of the technology (for example, many crop-management technologies) or the nature of the farmer (for example, farmers in more marginal areas) to avoid the potential of undermining incentives for private R&D.

- Developing institutional mechanisms (for example, specialized competitive funds) and appropriate legal frameworks for joint ventures between the public and private sectors, especially mechanisms that allow the private sector to adapt and test-market public sector technologies, with a share of the profits being returned to the public sector research institution.

- Rationalizing legal and institutional barriers on technology imports and releases so as to clearly define issues of public interest (for example, reduced public health hazards).

To fully harness these complementarities and synergies will require more attention to each sector's comparative advantage. However, it will be many years before the private sector assumes a large part of the R&D needs in most developing countries. In the meantime, public support to research must increase.

Private Research Foundations

Private foundations (for example, the Ford and Rockefeller Foundations) have been significant in supporting agricultural research, especially international research. Although private foundations exist throughout the developing world, this institutional approach has to date been most widely applied in Latin America.

Foundations have several advantages for supporting agricultural research. They represent an alternative institutional mechanism for raising and managing research funds from nontraditional sources, such as private corporations, agribusiness, philanthropists, and foreign donors. Foundations, as a type of NGO, have considerable flexibility in allocating and administering funds, and may be able to respond quickly to new research challenges. Foundations with an endowment are assured of funding stability at least for core activities. Finally, foundations may promote close links and responsiveness to client needs since these are often managed by boards with majority representation from private industry.

Agricultural research foundations have been established in various ways and for different purposes (box 2.4). Large private corporations have helped to establish foundations for social or public relations reasons. Others allow private firms that lack sufficient resources or skills to pool efforts and undertake joint R&D programs (Trigo 1987). Commercial farmers may support the establishment of foundations, such as the Agricultural Research Trust of Zimbabwe. In Latin America bilateral donors (especially the U.S. Agency for International Development) have helped establish research.

Box 2.4 Research foundations: A diversity of approaches

Foundation operations are as varied as their means of formation. Many foundations, reflecting their support from private business and from the U.S. Agency for International Development (USAID), focus on agribusiness development. The Jamaican Agricultural Development Foundation undertakes a varied program, including management of a competitive research grant fund and direct, venture-capital-type investments in agriculture. The CIBA-Geigy Foundation (in Mali) and the Agricultural Research Trust of Zimbabwe both operate research stations. The Agricultural Development Foundations of Peru (FUNDEAGRO) and Ecuador (FUNDAGRO) support development and operation of the NARI, as well as carry out their own activities. The Fundacion Chile, the Foundation for the Development of Polish Agriculture, and many other foundations promote agricultural investment and provide technology support to private agribusiness. Some foundations have been established in response to the frustration, especially of donors, with instituting reforms in the public NARIs.
foundations as alternatives to NARIs in several countries.

There are, however, problems with the foundations and some doubt whether many will be a sustainable long-term addition to the toolkit of NARs (Sarles 1990; Echeverría and others 1996):

- Foundations established without sizable endowments have encountered funding problems and found it difficult to raise funds from domestic sources. Some foundations started under donor projects had no long-term financial strategy and faced a crisis at the end of donor support. Endowments provide some independence and stability for a foundation (Horkan and Jordan 1996).  

- Foundations that depend on agribusiness and farmer support are likely to address only the needs of a minority of farmers, typically the commercial farmers. As a foundation's program becomes more commercial, it may crowd out legitimate private sector R&D activities.

- Foundations are often not well linked to the rest of the NARS, so that duplication or lack of complementarity in research may be a problem (Jarvis 1994). There may be little net additional benefit if foundations simply take over public sector research.

Experience shows that foundations can be an efficient and sustainable means of enriching the institutional mix of NARs. However, these successful experiences show that to ensure sustainability and effectiveness, foundations must be well endowed and have strong local support. Opportunities to establish foundations and the orientation of foundation activities in research will be highly situation-specific in capitalizing on unique funding opportunities, committed leadership, and specific development agendas.

Linking the National Agricultural Research Systems to Regional and International Research Systems

The global agricultural research system has evolved today into a complex system composed of (1) international centers (IARCs) with broadened mandates emphasizing natural resources as well as traditional germplasm products; (2) regional centers and networks; (3) private sector firms, many with large multinational R&D programs; and (4) an extremely diverse array of NARs, many with both federal and state systems. In a world in which costs of some types of R&D are high, especially for some basic and strategic research (for example, biotechnology), there is a strong rationale for NARs to link into a global system to capture spill-ins of technology and reduce the cost of technology development.

Technology Spill-ins and the Globalization of Research

A country may capture spill-ins by importing several types of technological products from the global system. These include improved technologies that can be released directly to farmers after initial in-country screening (direct spill-ins) or adapted through local research to fit local conditions (indirect or adaptive spill-ins). They also include scientific information, new knowledge, and methods for improving the efficiency of its own technology development efforts (knowledge spill-ins).

The ability to capture research spill-ins is particularly important for small NARs and for research institutes serving a small region or commodity that cannot justify investment in a full technology development program. The best sources of spill-ins are neighboring regions within a country, the IARCs, and countries with similar agricultural systems and agroecological features. A strategy emphasizing capture of research spill-ins can be very productive, but requires flexibility in the research system to identify and act upon opportunities arising from developments elsewhere. It demands that NARs recognize that careful screening of imported technologies is a legitimate scientific activity and an efficient use of scarce scientific talent.

Recent work has shown that potential spill-lovers, even for biological technologies, may be large (box 2.5). However, realization of these
Box 2.5 Technology spill-ins: Spreading research benefits beyond borders

Conventional wisdom has maintained that biological technologies are location-specific and must be adapted to local conditions, so that direct importation of technologies is not feasible. In the 1960s and 1970s this argument was used to justify investment in research in tropical and subtropical areas, where most agricultural research on food crops had been conducted, were poorly adapted to many developing countries. Since investment in research in developing countries now exceeds that in industrialized countries, the potential for spillovers between developing countries with similar agroclimatic conditions is much greater. The growing ability to use new information technologies, such as Geographic Information Systems (GIS), to describe like agroecological zones should greatly increase the precision with which spillovers can be targeted across countries, as for example between highland regions of the Andes and Himalayas. Research in some new technologies, especially biotechnology, is less location-specific than conventional technologies.

Recent work for wheat has shown that both potential and actual spill-ins of wheat varieties are much larger than expected (Maredia and Byerlee 1996). The cost of local research can be considerably reduced if a country, especially a small country, depends on imported varieties, since a testing program to screen imported varieties is only about one-third the cost of a full breeding program. It is clear that private R&D is organized to maximize spill-ins. Multinational seed companies, for example, usually establish only one major research station in a large country, or one regional station to serve several smaller countries. Imports of seed across countries with similar environments can be substantial (Echeverría 1991).

1. Other recent studies, such as Davis, Oram, and Ryan (1987); Evenson (1997); and Thirtle and others (1995), also demonstrate the considerable potential for international spill-ins of technology. A similar situation prevails in industrial countries where, in large countries such as Australia and the United States, half or more of the benefits of research in one state are captured by other states (Evenson 1994; Brennan forthcoming) and other countries (Thirtle and others 1995).

Spillovers depends on geographic proximity and historical and cultural links between countries. It also depends on policies, such as openness of the economy in exposure and incentives for private import of technology, as well as regulations and licensing requirements for importing chemicals and planting materials. Quarantine laws and local rules on testing and release of agricultural technologies also influence the degree and speed of spillovers. Finally, for importation of technologies to occur successfully and rapidly, considerable local capacity is needed to identify and screen technologies from abroad. Many NARSs do not yet have this capacity and indeed have been encouraged by donor support and national pride to follow a “self-sufficiency” policy with respect to agricultural R&D.

Governments can do much at the policy level to encourage technology spill-in. Specifically, countries need to minimize regulations that impede the import of technologies, especially for those embodied in production inputs, such as seed of improved varieties (Gisselquist 1994). Thus governments can:

- Eliminate import duties and non-tariff restrictions on the import of agricultural and research inputs
- Make seed certification voluntary and optional, while facilitating certification to the extent possible and enforcing “truth-in-labeling” laws for seed and other inputs
- Streamline seed varietal registration procedures. (Varietal registration might be made voluntary or, as an interim step, countries in a region can adopt common variety lists so that varieties approved in neighboring countries are automatically added to the approved list.)
- Rationalize regulations that restrict availability of agricultural chemicals, fertilizers, and pharmaceuticals by minimizing regulations designed to “protect” farmers and emphasizing those that address public health and environmental concerns
- Promote linkages to potential sources of spill-ins, such as IARCs, regional and international networks, and advanced research institutes (for basic research).
For any one commodity, the choice of research strategy with respect to technology development or screening of imported technology, will depend on the degree of local adaptation needed for imported technologies. It may be most appropriate to import widely adapted varieties from the international system and focus local research efforts on crop and resource management, which is likely to be more location-specific. The potential to realize spill-ins should be an integral part of research priority setting exercises.

**Linkages with International Research Institutions**

Participation in regional networks and linkages with national, regional, and international research centers can help to reinforce NARS research program quality and can be mechanisms to promote technology spill-ins (box 2.6). Most developing country NARSs are net importers of basic research knowledge from advanced research institutes in both developing and industrialized countries and from the IARCs. The need for linkages is often dictated by the small size or budget of a NARS, but linkages are of benefit to both parties (Lele 1995).

While technology spill-ins represent the most obvious rationale for international research linkages, NARS research programs may realize other indirect, but equally important, benefits from such international collaboration, including:

- Staff development through exposure to experienced researchers and other research programs
- New perspectives and approaches to addressing research problems
- Enhanced professional recognition in the global scientific community
- Access to advanced and specialized research facilities
- Access to international sources of funding for collaborative work.

NARS linkages with international research programs may be based on a variety of individual or institutional arrangements. Potential partners include public sector research institutes of industrial countries, private sector for-profit businesses, university research programs, development assistance-funded research programs, NARSs within the region or in other developing countries, and the IARCs.

Benefits from research linkages flow both ways (Lele and Coffman 1995) and research institutions in both the developed and developing countries should have incentives for collaboration. However, costs in the initial formation of collaborative research activities are high and often hard to defend in relation to other budget priorities.

**Box 2.6 Collaborative partnerships between IARCs and NARSs**

The IARCs were created to generate spillovers by producing international public research goods and services. They provide invaluable support for technology development by developing country NARSs. IARCs may often be low-cost providers of research products due to their ability to reap economies of size, but the IARCs too are facing budget pressures and are being forced to focus programs and reduce some of their training, assistance, and technical advice and support. Discussions between the IARCs and the NARSs to exploit complementarities can improve resource allocation. Complementarity is fostered by joint decision-making on the types of products to be provided by each party, and also by the fact that, in practice, most products are developed jointly (Maredia and Byerlee 1996). Recent moves to develop consortia and two-way contracting arrangements between NARSs and IARCs are a useful move in this direction.

1. IARCs are relatively more important to small NARSs. However, the greatest absolute advantage is captured by large NARSs (Maredia and Byerlee 1996).
2. The CGIAR renewal process and the Global Forum for Agricultural Research recognize regional associations as the desired mechanism for liaison between IARCs (and advanced research institutes) and the many individual NARSs. This provides consultation and NARS input into developing research agendas and should assist in disseminating IARC research results.
In summary, NARS linkages to the global research system are important to facilitate technology spill-ins. Extensive international contacts and linkage arrangements between scientists, often with support from donor funding, will promote sharing of technologies, as well as efficiencies in technology development. A variety of institutional mechanisms is needed to exploit international complementarities and development of such institutional linkages is a significant aspect of maturation of NARSs. For problems and commodities not addressed by IARCs or advanced research institutes and in regions with small countries, regional research initiatives may play a greater role.

Regional Agricultural Research Associations

In recent years regional research collaboration has received renewed interest as a way of realizing efficiencies in NARSs, especially in regions with many small countries (Eyzaguirre 1996). Regional agricultural research associations (RARAs) have evolved as formal organizations formed by NARSs (usually by the NARIs) to provide a structure for integrating regional technology programs under NARS-directed management and capturing the efficiencies offered by regional approaches. Regional associations have become more active as both donors and NARSs face problems of declining budgets and as the increased maturity gives NARSs the confidence to seek regional collaboration. RARAs have also been stimulated by the upsurge in regional economic groupings and free trade associations.

Several new initiatives are directed towards strengthening and working with the RARAs. These initiatives represent a major shift in priority to RARAs and imply a substantial increase in support to and through these institutions. The regional collaboration and linkages can operate at various levels of integration, including:

- Informal and formal networks to share research results, ranging from exchange of research publications and journals, to regular visits between different NARS programs, to joint technical meetings and review of work of common interest. Such sharing of information is relatively low-cost and worth promoting to the fullest extent possible.
- Integration of research programs through joint development of research strategies and plans, with different cooperating partners undertaking specific aspects of the work, sharing results, or agreeing to use a common facility (laboratory, station, germplasm bank, equipment, or library). Regional research networks sponsored by some IARCs are examples of such joint planning and cooperation.
- Joint funding of research in a fully integrated program. The most ambitious scheme of this type is the Regional Fund for Agricultural Technology in Latin America, which will distribute funds for regional research priorities through competitive grants (box 2.7).

The level of activity of the RARAs and the heavy donor support in many cases pose challenges to the sustainability of such initiatives:

- Over the long run RARAs must develop strategies for funding and operation that

**Box 2.7 Latin American Regional Research Fund**

A good example of a regional research undertaking exists in Latin America, where the Inter-American Development Bank and NARSs of Latin America are establishing a Regional Fund for Agricultural Technology, which will be operated under a regional endowment to provide funding through competitive grants for priority regional research activities (IDB 1996). The fund will encourage and finance strategic research of regional applicability on a medium- and long-term basis, provide a forum for discussing agricultural technology policy, facilitate exchange of information and technology, and facilitate representation of regional views in international forums. Priorities for competitive grants will be based on the potential to maximize regional spillovers. National, regional, and international organizations and private sector firms will be eligible to submit proposals for funding.
overcome the current heavy dependence on donor support. This dictates a need for regional centers and networks to be kept small, to operate on modest levels of funding, and to seek sustainable sources of finance.

- Regional initiatives must address high-priority problems in the region and not donor fads. Greater NARS control of the governance of RARAs combined with financial contributions by the NARSs themselves are necessary elements to ensure that RARAs address NARSs needs.

- Regional research priorities are best developed in conjunction with national research priorities (Spurling and others 1992). Regional programs should be complementary to and supportive of NARS programs, and must identify appropriate operating roles and mechanisms to avoid becoming an additional layer of bureaucracy.

To ensure the long-term relevance of research programs, RARAs must broaden their base to include research participants other than the NARIs, such as public and private universities, private firms, and others.

RARAs need independent leadership from the NARSs, patience, innovation in seeking sustainable financing, and stable support from donors. The NARSs must develop real ownership of the RARAs and ensure that RARAs are a cost-effective mechanism for executing research.

Notes

1. For example, private companies may overinvest in developing new pesticides relative to investment in integrated pest management technologies and new, pest-resistant varieties.

2. Although this discussion uses the term "competitive grant," the principles are equally valid for competitive contract research. The difference between the two is simply the degree of control the funding agency exercises after the work is awarded.

3. Even in such systems, some recent evidence questions the productivity of CGs (Huffman and Just 1994).

4. An ISNAR study (Hoste and others 1995) found that in Benin and Nigeria the number of scientists was about equally split between the governmental research institutes and the agricultural universities. In Chile the number of scientists and their qualifications are higher in the universities than in the NARI (E. Venezian, Catholic University of Chile, personal communication 1995).

5. By 1992 fully one-third of the maize breeders in Latin America and Asia (outside China) and over one-half of related research expenditures were in the private sector (Byerlee and Lopez-Pereira 1994).

6. In the U.S. hybrid seed industry, public sector inbreds accounted for one-half of the inbreds used up to the 1960s, some 30 years after the initiation of private sector R&D. In developing countries outside China hybrids based on private R&D make up only 60 percent of the sales of hybrid maize seed by the private sector; the rest of the hybrid seed sold by the private sector is based on hybrids developed in the public sector (Lopez-Pereira and Filipello 1994).

7. For example, the United Brands Company and the Honduran Agricultural Research Foundation, the CIBA-Geigy Foundation and the Cinzana Research Station in Mali, and Fundación Polár in Venezuela.

8. Larger endowments have generally contributed to a stronger organization, although there may be a trade-off between a large endowment, which provides independence and more modest funding that forces the organization to remain active in seeking additional funding and being responsive to clients.

9. In some NARSs there have been jealousies between relatively well-funded foundation programs and government programs, which may have a similar mandate but are encumbered by limitations on salary levels and operating flexibility.

10. Only recently and mainly in Africa, where there is a prevalence of small NARSs (24 out of 48 countries), has there been much emphasis on regional research initiatives (Spurling and others 1992; Weijenberg and others 1993; Weijenberg and others 1995; and Taylor and others 1996).

11. Industrialized countries are also major importers of agricultural technology.

12. The CGIAR Global Plan of Action to strengthen global agricultural research is based on consultation with regional forums of NARSs and includes a strategy of strengthening these regional forums (RARAs).
CHAPTER 3

Strengthening Public Research Institutes: Issues and Good Practice

Public research institutes—the NARIs—are faced with the dual challenge of obtaining increased funding support while improving their relevance and efficiency within the evolving national and global research system. Most of the effort in reforming NARIs over the next decade must be focused on making more efficient use of the available physical and human resource infrastructure for research. Relatively little effort should be expended on their further expansion.¹

The key issues for the NARIs are as follows:
- Increase funding and diversify funding support
- Undertake institutional and organizational changes to allow more efficient and flexible management
- Enhance efficiency by improving methods and capacities for planning, priority setting, and evaluation
- Implement human resources management systems to attract and motivate scientists and develop research leadership
- Strengthen the client orientation of research and expedite technological transfer to users.

Responding to the Funding Crisis

Public research institutions in almost all countries have suffered from a funding squeeze as the number of scientists (and sometimes their salaries) have grown faster than the total research budget. The result has been manifested in severely reduced operating costs, fewer purchases, and less maintenance of capital items. This has led to declines in staff morale and serious threats to the productivity of many research systems. Coupled with the lack of funds is the problem of extreme volatility in funding. Uncertainty in funding is especially damaging in agricultural research because of the long-term and continuous nature of much research (box 3.1).

The reasons for the funding crisis are varied and include the following interrelated factors:
- Implementation of fiscal austerity leading to cuts in general government budgets
- Undue dependence on a single source of funds (such as annual appropriations from general tax revenues)
- Lack of understanding by decisionmakers of the public-good nature of much agricultural research and poor links between NARS managers and policymakers responsible for budget allocations
- Lack of evidence of the results of research or failure to communicate that evidence to policymakers
- Disenchantment of policymakers because of the perceived inefficiency of public research systems
Box 3.1 Funding reliability in the short term

In many NARSs reliability in allocation of the approved research budgets is a serious problem. Agricultural research is seasonal and late release of funding can mean complete loss of a year's experiments and waste of funds already spent. Problems with dependability of fund releases are embedded in the general budget procedures of many countries: occasionally the problem is worsened by administrators' lack of appreciation for research. Failure to address financial management problems can jeopardize the viability of research institutions. In Sub-Saharan Africa this problem is especially acute and no general solution has been found. Practices that can at least partially alleviate the problem include: improving the overall government budget release system, advancing fund releases on a six-month basis, giving greater autonomy to research institutions (including flexibility in financial management), streamlining procedures for approving expenditures, and using revolving funds.

- Lack of political support for research from farmers, farmers' organizations, and agribusiness
- A decline in agricultural commodity prices inducing a reduction in research funding.

The funding problem can be tackled at two levels: by building political support for public funding and by diversifying away from dependence on public funds by tapping alternative sources of funding such as those generated by the commercialization of technologies or by cost-sharing with farmers. Increases in donor funding can provide temporary relief, but all NARI institutions must develop sustainable financing strategies based on local sources of funding (Ellsworth 1997).

Building Political Support for Public Sector Funding

The first order of business must be to restore political support for public funding of agricultural research. The current slowdown in funding should be seen only as a temporary aberration in what should be a long-term trend toward increased public investment in agricultural research. The example of the United States is highly pertinent. There, investment by the public sector in agricultural research grew in real terms at 4 percent annually over a 100-year period: even during the austere 1980s and 1990s public funding for agricultural research continued to increase, although slowly (Fuglie and others 1996; Alston and Pardey 1996).

Research intensity in developing countries, averaging about 0.5 percent of agricultural gross domestic product, is significantly lower than in industrialized countries (more than 2 percent). This reflects the low tax base and the high share of agriculture in developing country economies. Poorer countries typically allocate an equivalent proportion of the agricultural sector budget to agricultural research as do richer countries (Elliott and Pardey 1988), but spread over a relatively large agricultural sector, this results in low research intensity. However, the lower research intensity in developing countries often implies a low priority for agricultural research.

Appropriate research intensity is a function of the stage of development: it is not useful to assign arbitrary quantitative targets, such as 1–2 percent of agricultural gross domestic product (AgGDP), for all developing countries. The main task is to ensure that both real research budgets and research intensity are increasing over time in a consistent and sustainable manner. At present, most countries do not even comply with this more modest objective.

Despite the clear rationale for public sector funding, few countries have built an adequate political base for agricultural research over the long term. There is no universal recipe for developing such a support base, but better communication of the needs and benefits of research is critical. Some potential elements of a strategy to build a support base are:

- Documenting and publicizing the impacts of research. Although agricultural research is integral to achieving the national objectives of food security, poverty reduction, and environmental conservation, NARIs have generally done a poor job of presenting the case in a form readily un-
understandable to political leaders and administrators. There is still little evidence of the returns to specific types of research and, even in some large and relatively strong NARSs, such as India, there have been few recent studies of research impacts. Research institutes must put more emphasis on advocacy and public awareness for policymakers, farmers, and other constituents.

- Developing strong and articulate client organizations that have a political voice and that can act as lobby groups for agricultural research. While organizations of commercial farmers are common and in many cases contribute directly to research funding, organizations of small-scale farmers with political influence are rare. Yet farmer organizations have been important in speaking out for agricultural research funding in most industrialized countries. Agribusiness and environmental groups can also be important supporters of research programs. The recent democratization of the political system in many countries has encouraged the development of such organizations, which have potential in the long term to provide a constituency for agricultural research.

- Reforming the management and effectiveness of public sector research institutions to make these attractive to investors. While this issue is addressed in detail elsewhere in this paper, the lack of funding support in part reflects perceived inefficiencies and lack of impacts of research organizations.

- Developing close relationships and good communication between NARI administrators and policymakers charged with budget allocations. In countries where links to budget officials are strong, research budgets have suffered less. Having policymakers and clients of the research system on the boards of research institutions is one way to improve communication. For the World Bank, the ongoing dialogue with ministries of finance provides an excellent opportunity for clarifying the importance of a well-functioning agricultural research system.

- Broadening the stakeholders in agricultural research beyond the traditional agricultural base. Research programs can exploit funding from other ministries, such as environment, science and technology, and commerce and trade. The recent increase in funding for environmental issues offers an opportunity for agriculture to persuade environmental groups that agricultural research can contribute to solving environmental problems.

**Commercialization of Research Products and Services**

There are alternatives for increasing funding of research in public research institutes through commercialization of research products and services, including: sales of research products and services (for example, sale of basic seed), sales of nonresearch products and services (for example, soil tests), and various forms of joint ventures. The benefits of these options are contingent on revenue from commercialization being returned directly to research institutions (and being additional to their budgets) rather than being returned to the general treasury.

The sale of research products from the public sector, through some form of royalties and backed by adequate intellectual property rights, has sometimes been successful in funding research operating costs. For example, the Brazilian maize program receives a large share of its operating funds from the sale of basic seed to private seed companies (Lopez-Pereira and Garcia 1994).

Research systems can also generate revenues through sales of nonresearch products and services, such as soil and chemical testing, diagnostic tests, sale of commercial seed and vaccines, staff consultancies, and even commercial agricultural production. Such activities can sometimes be justified, where there is surplus capacity in research establishments, and revenues from commercial activities can help maintain the basic research infrastructure.
However, in the longer run, the most efficient approach will be for the public sector to sell off excess research infrastructure.

Finally, public research institutes are increasingly entering joint ventures with the private sector either through a private company contracting research in the public sector or through agreements with private firms to adapt a research product from the public sector to specific markets, test a product widely, or undertake market development. Joint ventures that share the costs and benefits of R&D are being developed in many countries for genetic improvement, seed production, plant propagation, and veterinary products. While currently affecting only small segments of the overall research system, such schemes are bound to grow as market mechanisms become more prevalent in guiding agricultural development and R&D activities.

With the prevailing constraints in public funding for research and with the increasing commercial orientation of agriculture in developing countries, commercialization of public sector research products and services will clearly be significant in future funding. This also represents a means for NARIs to serve the needs of expanding agribusiness. A reasonable expectation is that, in low-income countries, 10 percent of the budget of public sector research institutions might be generated through these means, and up to 20–25 percent in middle-income countries. Although these funds can potentially provide an important share of operating costs, they are often linked to specific topics or commodities and to commercial agriculture and do not resolve the problems of funding other types of research, especially for small-scale agriculture.

The main policy issue for such arrangements is to ensure that public sector research is seen as being, and remains, motivated by broader societal objectives and is not perceived as having "sold out" to industry. For this reason commercialization of technology should be approached with caution, as it can quickly distort program priorities and attention. Before engaging in commercial activities, each public sector institute should develop a clear and transparent policy for ensuring that such commercialization is consistent with the public interest, applying intellectual property rights to protect technologies developed fully or partly with public funds, providing free access to protected technologies to other public research institutes, and sharing revenues between the central administration of a research institute, the department that undertook the work, and the scientists generating the technology. Special caution is needed in commercializing non-research products and services to ensure that this is a complementary, not competitive, activity to the main business of research institutes (box 3.2).

**Farmer Financing of Research through Industry Levies**

Funding for research in public institutes can also be generated through some form of industry levy on agricultural output, or by contributions from producer associations, usually fixed as a certain percentage of total sales of a product. From an economics perspective, research levies can be an efficient way to fund research (Alston, Pardey, and Roseboom 1997) and are also equitable since the cost of research is borne by those who benefit (that is, large producers contribute more but also receive more of the benefits). This form of funding is increasingly common for some commodities and for commercial agriculture. It works best for commercial products that pass through a concentrated marketing channel making it administratively feasible to collect the contributions or levy. The most common examples are for export crops, where a marketing monopoly often facilitates the collection of the levy. It is also feasible for food crops produced commercially and with strong producer organizations, and even for basic food staples produced by small-scale farmers, if the product passes through a narrow marketing or processing channel (for example, a food marketing corporation or a few large grain mills). It is least appropriate for traditional food crops (for example, cassava)
### Box 3.2 Five key questions to ask on cost recovery in public research institutes

While there may be potential for generating significant additional funds from research programs (especially in areas where commercial agriculture is important), a number of critical questions have to be faced in establishing a policy for commercializing research:

- **If** the sale of research products is feasible and profitable, why should the public sector be involved in the research in the first place? The private sector should be encouraged to take over these areas of research directly. Indeed, public sector participation in such activities with support from the public purse may undermine private sector entry into the R&D activity.

- **If** the public sector is motivated by financial rewards, will its research be directed to more favored regions and farmers at the expense of small-scale farmers and more marginal areas that may be the primary target of national policy? Reliance on the sale of research products will also bias research away from crop- and resource-management research, where there is little opportunity to earn revenues from the sale of research products.

- **If** a public institution sells nonresearch products, will this reduce research outputs? Sales of research products may complement research efforts, but the sale of non-research products and services can quickly distract scientists from their main task of developing new knowledge and technologies, and result in research institutions acting as state farms and businesses.

- **If** technologies are to be protected by intellectual property rights, research managers must ask what is the cost of collecting revenues from contracts and royalties relative to the funds generated? A research institute that seriously pursues intellectual property protection will need to establish a specialized office with the appropriate legal and business skills for negotiating with private companies. The revenues raised from these sources often do not pay the extra costs incurred.

- **If** research is successful in the sale of new technologies, should some of the funds received be used as incentives for rewarding the scientists responsible for developing the product? This provides a logical incentive mechanism for researchers, but immediately raises issues of equity and incentives for public sector employees.

1. Recent sales of basic seed as a source of revenue for maize researchers in China and Mexico appear to be shifting incentives away from research for the marginal areas that are ostensibly targeted by government policy.

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that pass through informal marketing channels. To be effectively implemented it should be initiated and supported by farmers who see it as in their interest, as beneficiaries, to contribute to funding agricultural research. However, legislation is usually needed to ensure that the levy is obligatory on all farmers and to avoid “free riders.”

While farmer financing represents a valuable potential source of funds for public research institutes, its real value is only realized if farmers’ contribution to funding is combined with farmers’ participation in setting the research agenda, thus producing a more demand-driven research system. Where funds are collected through producer associations, the association can determine or influence the research priorities for expenditure of the funds. In other cases some type of research board or corporation in which farmers and other industry representatives have a controlling or major vote can be the vehicle for distributing funds. This is the model used in Australia, where 16 research corporations have been set up as partnerships between industry and government to administer the research funds collected from all major agricultural industries.

Where feasible levies for research should be encouraged with appropriate institutional means to ensure farmer participation in determining the level of contribution as well as setting priorities for the research to be funded. This approach will work best with matching government funds. This is because farmers will typically focus on short term research priorities at the expense of more basic and long-term research, or research with broader societal benefits (for example, protection of the environment). Government provision of matching funds can be accompanied by scientists, poli-
cymakers, and the wider community joining farmers in determining research priorities, to represent these long-run and broader interests.

**The Role of Donors and International Development Banks**

The NARI funding crisis raises difficult issues for donors who have been important contributors to the growth in investment in agricultural research over the past three decades. Initially, donor contributions were largely limited to capital development. However, because donor-driven expansion of the research system often resulted in a large physical and human capital base that could not be maintained or used effectively because of shortage of operating funds, donor contributions soon extended to operating budgets. Donor support to agricultural research is most pronounced in Africa, where donors accounted for nearly one-half of the total research budget of NARIs in 1990 (Pardey, Roseboom, and Beintema 1997).

Such extensive donor support has been criticized for its unintended negative impacts on NARI development. Some potential pitfalls from donor financing of research systems include: creating donor dependency, causing fragmentation of research efforts, creating lack of continuity in programs, increasing requirements for “counterpart” funding for recurrent costs, making ineffective use of some donor-provided inputs, and failing to link research funding to policy reforms (Byerlee and Alex 1997). It also has been argued that NARS managers find it easier to obtain funds from donors than to develop political support for local funding especially in NARIs where donor support covers the major part of the national research budget (Trigo 1987; Rukuni 1996).

Donor funding of agricultural research programs will undoubtedly remain an important element of development assistance programs, as research investments offer high rates of return and provide mutual benefits to donors and developing countries. To minimize the negative effects of donor support, assistance should be based on well-developed national research strategies, long-term support for targeted research programs, development of mechanisms for sustainable financing for research, more effective use of existing resources, careful prioritization of donor-funded inputs (especially of costly technical assistance), and flexible linkage of research funding to institutional and policy reforms. All of this requires strong NARI leadership (Byerlee and Alex 1997). This suggests that donors should support research by using every opportunity to:

- **Shift from project funding to providing block funds or competitive grants for capital and operating expenditures for agreed-on high-priority research activities.** This system is being tested in “Frameworks for Action” between donors and NARSs in some African countries, including Mali and Tanzania (SPAAR 1996).
- **Change focus from investing in capital-development projects to stimulating institutional changes that improve the use of existing resources; this is already under way in many countries.**
- **Emphasize projects that have an explicit objective of increasing local funding for NARIs.** These might include developing farmer organizations, sponsoring impact studies, and developing mechanisms for tapping private industry funding.
- **Foster greater private sector R&D investments through supporting policy reforms aimed at encouraging private initiative in all sectors, and through projects specifically targeting private-sector R&D (for example, support to establish an enabling legal and administrative environment).**
- **Encourage dialogue between ministries of finance and the managers of the NARIs to create more sustainable funding arrangements.**

In summary, donors, including development banks, must give explicit attention to sustainability of research funding. This implies reducing total dollar contributions and giving greater emphasis to improving research quality as opposed to expanding programs. Second, donors must closely coordinate their activities
with each other and with NARS priorities to ensure that the support is complementary and addresses key strategic technological and research management issues.

**Organizing National Agricultural Research Institutes for Increased Efficiency**

Two dimensions of research organization provide the context in which efforts to increase efficiency must be made. These are the degree of autonomy of research organizations and the degree of centralization.

**Autonomy of Research Organizations**

In many countries the pursuit of science in the public sector within the rules and regulations of the civil service has resulted in low productivity of scientists. Given the special requirements of research (box 3.3), there has been a worldwide move to grant greater autonomy to research organizations outside civil service regulations. Autonomy is expected to give institute management and staff the flexibility needed to tailor business rules and regulations and human resources management to the specific needs of research. It also provides the flexibility needed for financial management, because research operating costs as a proportion of total budget are higher than for many other governmental departments, and costs and types of expenditure are more variable over time.

While many agree in principle on the need for autonomy in research organizations, there is little agreement or understanding of what this means in practice. The degree of autonomy granted may vary from delegating research organizations limited power on financial and human resources decisions to full autonomy in research governance that allows the organization to set and change its own rules of business.

A research organization may be completely privatized (as in New Zealand), even though much of its funding still comes from the public sector. Table 3.1 provides a summary of the various administrative, financial, and personnel decisionmaking powers that need to be considered in granting autonomy to a research organization. In practice, in setting up "autonomous" research organizations, only a few of these powers have been delegated to these organizations.

Institutional autonomy (or semi-autonomy) may be provided to an apex research policy

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**Box 3.3 Why is research different from many public sector activities?**

- Research is a creative process with uncertain outcomes and cannot be micro-managed from day to day. Good scientists require flexibility and independence over a long period to achieve results.
- Recruitment and promotion of scientists requires different standards than those for civil service employees. Scientific skills are highly specialized and scientists require opportunities for advancement in rank and salary within their specialized areas. In a competitive international market special incentives and rewards are needed to attract and retain the best scientists.
- Research often requires lumpy recurrent and capital costs (for example, setting up an experiment) that demand considerable flexibility in financial and procurement arrangements. A broken irrigation pump that is not fixed because of rigid procurement rules or financial stringency, can wipe out years of experimental work.
- Research managers need flexibility to shift resources among the major budget categories of operating costs, capital equipment, and salaries to ensure overall efficiency and adequate operating costs.
- Research institutions require flexibility to diversify their funding support by soliciting funds from various ministries, the private sector, or internationally, and by commercializing research products.
- Diverse stakeholders (government, producers, agro-industry, and the broader scientific community) should be active in setting the research agenda. When research is controlled and managed directly by line ministries or departments, many stakeholders may be marginalized from these processes.
Table 3.1 Definition of “autonomy” in terms of the types of flexibility required for various management functions

<table>
<thead>
<tr>
<th>Function</th>
<th>Flexibility needed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Governance</strong></td>
<td>Selection of Board members in their personal capacity, development and approval of rules of business, and open and transparent selection of a chief executive officer free of political interference.</td>
</tr>
<tr>
<td><strong>Research programs</strong></td>
<td>Development and approval of annual research plans, allocation of research budgets, and monitoring and evaluation of research activities.</td>
</tr>
<tr>
<td><strong>Personnel management</strong></td>
<td>Independent, transparent, and merit-based selection of research leaders and scientific staff, performance-based salary and promotion, dismissal of unproductive staff, and merit- and skill-based selection of staff for training.</td>
</tr>
<tr>
<td><strong>Administrative procedures</strong></td>
<td>Independent procurement of supplies and equipment with internal accountability mechanisms and flexibility to employ short-term consultancies.</td>
</tr>
<tr>
<td><strong>Financial management</strong></td>
<td>Flexibility to obtain funding from any source (including borrowing), retain and use generated income and acquire and sell capital assets, and set procedures for disbursement.</td>
</tr>
<tr>
<td><strong>International collaboration</strong></td>
<td>Power to enter into agreements with international institutions for research collaboration and scientific exchanges.</td>
</tr>
</tbody>
</table>


advisory committee, an apex research funding entity, a research executing institution, or a combined funding and executing agency. The general trend has been toward forming semi-autonomous apex research councils to provide independence in strategy and programming, or to create autonomous research organizations or corporations that combine apex policymaking roles with research execution. In practice, many of these so-called autonomous research organizations have not lived up to expectations because governments have been reluctant to delegate real powers and because many scientists themselves feel more secure working under civil service regulations. Even research organizations that have been given considerable autonomy have often not used these powers so that business rules differ little from those in the civil service. In other cases business rules have not been well defined, leading to tensions with the civil service over which rules always apply.

Autonomous research bodies must recognize that, in return for freedom to manage their financial, human and physical resources, they must be held accountable in delivering research products. This requires medium-term and annual plans that include specific measures of research output and indicators of performance that can be used by the governing board and funders to evaluate the organization. In return for freedom in day-to-day management, research organizations will have to devote more time to planning and assessment than they have done in the past.

Granting of autonomy to research organizations must start with governance of the organizations. Few research organizations have succeeded in establishing the professionally competent and independent Board of Directors...
Basic to functional autonomy. The usual practice has been to appoint ex-officio members representing government departments, with the minister of agriculture as chair.

The most successful examples of autonomous research organizations have created research corporations that fit all or most of the requirements of table 3.1. These corporations, which now exist in countries as diverse as New Zealand, Colombia, and Uruguay, have adopted business practices for financial and personnel management, and salaries, similar to those of private companies. Their creation has often been associated with a significant downsizing of staff, made possible by increased flexibility in personnel management.

The privatization of research in the form of research corporations offers much potential for improving the performance of agricultural research institutions, especially for research execution. However, it represents a radical departure from the conventional view of public sector research and experiences with this model should be carefully monitored as a guide to implementing it more widely. In the meantime, the following guidelines represent the current state of knowledge in granting autonomy to research organizations:

- The respective tasks of autonomous organizations in research execution and funding and in research policy should be clearly defined.
- The composition of governing boards, including the Board chair, should shift from institutional representation toward appointment of professional members who are respected scientists and stakeholders appointed in their individual professional capacity.
- Autonomous organizations should be linked to the different stakeholders, who should be active in its governance and financial support.
- Alternative mechanisms, such as policy advisory committees, should be explored as these can provide policy input into setting priorities for autonomous research organizations.

In establishing autonomous bodies, expert advice in public sector management is required to carefully define and agree on rules and regulations for managing financial and human resources and capital assets. Granting autonomy in some areas without flexibility in other areas will severely constrain the operation of the new organization.

- Autonomous bodies need well-defined mechanisms to ensure accountability to those who fund them. The mechanisms should define specific outputs over a given period with built-in milestones that can be monitored at regular intervals to assess progress.

**Centralization of Research Funding and Execution**

Public sector research in many countries has typically been highly centralized with the degree of centralization tending to increase over time with the formation of a large national research institute (that is, the NARI) and central research institutes for particular commodities or agro-ecosystems. Another favorite vehicle for centralizing and coordinating research efforts has been the national coordinated research programs, usually organized along commodity lines.

One rationale for centralizing research is the potential for economies of size and scope, arising from high fixed costs for much research, specialization of scientific expertise and equipment, and opportunities for team interaction. But several factors may lead to diseconomies of size in research, including higher transaction costs in conducting research for a larger and more dispersed mandate area, lack of competition among rival research programs, and increased institutional and technological risk (for example, genetic uniformity).

The potential for economies of size in research is largely an empirical question. Because of the substantial overhead cost of experiment stations, libraries, and laboratories, the major factor determining economies of size is the
market size over which a technology will be applied (Byerlee and Traxler 1996). This argues for centralizing those research activities which produce technologies with wide applicability (for example, much basic and strategic research and some applied research such as varietal improvement). For example, national coordinated programs have been effective for conducting applied crop-improvement research over diverse agro-ecosystems. However, crop- and resource-management research tend to be more location-specific and there is little indication that centralizing this research is effective.

Another issue involves centralizing funding of research—especially the relative share of research to be provided by national, state, and local governments. The main rationale for centralized funding is that state and local governments have few incentives to fully fund research, which generates spillovers beyond their jurisdiction. However, research that has mostly local applicability, especially adaptive research, can and should be funded locally, where possible. For adaptive research, there is a strong case for decentralizing to the district or county level, with local governments picking up a share of funding. There is also much potential for beneficiaries to fund adaptive research and participate in research priority-setting. The closer that research is to the user, the more likely it is that users can participate in this way. These considerations suggest that some advantages of economies of size and market size for centralized research systems will be offset by the potential for user participation in a more decentralized research system.

In summary, the optimum organization of research will be a complex tradeoff of efficiency issues, duplication versus competition, institutional pluralism versus central control, and centralization versus proximity to and interaction with users. The optimal organization of research will probably be different for funding research and for executing research: these will be increasingly separated in the future. Centralized NARIs will probably become more specialized in basic and strategic research and management of national research networks, while much of the applied and adaptive research increasingly becomes decentralized and administratively independent in regional research centers in which farmers are involved in funding and priority setting.

**Institutionalizing Research Planning and Evaluation**

In the past decade many NARIs, usually with World Bank or other donor support, have undertaken strategic planning and priority-setting and introduced more formal methods for evaluating research projects before funding (Odame and Setshwaelo 1997). Typically, the results of this work are embraced in a master plan for the NARI, which details overall research system strategy, including details on research priorities, organizational structure, physical facilities, staff development, and institutional linkages needed to implement the strategy.

**Research Planning and Priority Setting**

Research “master plans” have often been required as a condition for a project loan or credit. A recent survey of 37 countries in Sub-Saharan Africa (Maredia and others 1996) reported that 18 had completed research plans, 12 had plans under preparation, and three were going to prepare plans. However, despite the proliferation of master planning in NARSs and the apparent benefits in terms of donor project implementation, the impact on research efficiency and funding has been less than expected. Several reasons account for this:

- Strategic planning and priority setting have often been seen as being imposed from outside and in too many cases, master plans have been developed by outside consultants with little local input (Ravnborg 1993; Anandajayasekeram and Rukuni 1994). Most NARSs lack the analytical capacity to undertake planning and priority-setting work as a continuing activity. As a result, most exercises have been one-shot
affairs with a tendency for the plan to be forgotten once the donor has signed off.

- Too much attention has been placed on developing quantitative estimates of resource allocation within the public-sector NARI, at the expense of analysis of broader subsectoral and science policy issues, including postharvest issues, the potential role of the private sector and its links to the public sector, and the opportunity to import rather than develop new technologies. As a result most master plans, despite the range of detail on the research system, lack vision for the future development of the whole technology system for the subsector (Boughton and others 1995).

- Nearly all analysis of research priorities has been carried out at the macro level to analyze priorities across programs. However, research decisions are made operational at the project level and there has been no effective mechanism to move from the top-down program planning to the bottom-up annual cycle of project formulation for funding. As a result, the funded projects in aggregate are often inconsistent with macro-level priorities.

- It has proved very difficult to make the hard decisions to close down unneeded facilities and reallocate staff and budgets in line with priorities, so that priority setting has often not been translated into practice.9

Success in research-planning and priority-setting depends much on the processes for undertaking the planning. In the past too much emphasis was placed on refining the analytical techniques employed. Institutional processes for research planning should include the following general steps (Collion and Kissi 1995): assessment of the external environment; assessment of the current status of the organization, projection of desired future state of the organization, analysis of the gap between existing and desired state, determination of a strategy to close the gap, formulation of an action plan, implementation of the action plan, monitoring and evaluation of implementation and outcomes, and adjustment to strategy and action plan, as appropriate. Major stakeholders should be involved as full partners at each step in the process to increase the quality of information used and to help build political support for the strategy as well as for the research system (Ricks and others 1997a).

As NARIs develop more experience in planning and priority-setting, there will be more examples of good practice. Experiences over the past decade provide lessons that can be applied in developing capacity in future priority-setting exercises to address weaknesses in the master planning approach:

- Analytical work to guide research planning is best undertaken from within the research system, preferably by a small unit with ready access to senior research managers (Alston, Norton, Pardey 1995). This implies that donor support for priority-setting should shift from providing up-front consultancies for master planning efforts to developing institutional capacity building within NARIs. This will necessarily be a longer-term exercise, but will result in more effective ownership of the results.

- The establishment of an analytical unit for research priority setting should be accompanied by strong commitment of research managers to ensure that results will be considered in decisions on research-resource allocation and that, in fact, research resources shift in ways consistent with identified priorities.10

- Analysis should be broadened beyond mechanistic allocation of resources by program to include work on linkages between agricultural policies and agricultural research policy, research resource allocation, and the economic evaluation of the effects of previous research. Analysis should take a comprehensive view of the R&D system, including the rapidly growing participation of the private sector in many research areas, which may influence the priorities of NARIs.

- The process should be participatory including a wide cross section of scientists,
and the main stakeholders—policy makers, research partners, and clients. At lower levels of planning and priority-setting, participation of users should increase relative to participation of policymakers, so that in the design and selection of research projects, the main interaction should be between scientists and farmers. At the project level successful design of projects depends more on using relevant participatory process and appropriate scientific method than on the employment of formal priority-setting methods.

The Role of Economic Analysis in Priority Setting

In recent years economic methods for research priority-setting have evolved rapidly and can now provide valuable information to decision-makers for more effectively allocating research resources to meet national objectives. Master planning exercises typically employ some form of economic model to analyze research resource allocation. However, there have been a number of difficulties with the approaches used:

- The methods used for analysis of research priorities have often been inappropriate, in part because of lack of consensus within the economics discipline on appropriate methods. In particular, weighted scoring methods have been widely used, even though the criterion variables and the weighting methods have sometimes had little, if any, basis in economic theory (Alston, Norton, and Pardey 1995).
- There has been a lack of data to compare actual resource allocations to indicated priorities, or to monitor shifts in resource allocations over time in relation to the priorities. Without information on current resource allocations, it is impossible to know the direction in which resources should be shifted, even after the formal priority-setting exercise is carried out.
- In most cases analysis has focused on resource allocation across commodities, with little effort to estimate expected costs and benefits for non-commodity programs, or to assess resource allocation over agro-ecological zones. In practice the latter resource allocation decisions are often more strategic.

Economic analysis can also be applied at the project level to estimate ex-ante cost-benefit ratios as a basis for selecting projects. This approach is being applied in some NARIs, and in Australia is a requirement for project submission for many funding agencies. At this stage in the development of analytical capacity in priority-setting, the use of ex-ante cost-benefit analysis at the project level should be approached cautiously because:

- Research is an inherently risky activity with outcomes that are difficult to estimate ex-ante.
- The impacts of some types of research are difficult to measure or value (for example, basic research or research on natural resources management).
- The success of a research project depends critically on its scientific merit as well as on its relevance to solving real problems. Undue emphasis on ex-ante economic analysis may detract from efforts needed in areas such as peer review and client interaction.
- Resources required to conduct a rigorous economic analysis of a research program or project are considerable if the results are to be credible to scientists and funders. Economics skills in most NARs are scarce and the opportunity costs of employing these in economic analysis of projects relative to other activities (for example, economic evaluation of technologies and diagnostic surveys) are high.

In summary, economic analysis in setting research priorities should be encouraged at the program level and should be broadened to include noncommodity research. NARIs need to develop the capacity to conduct such analysis on an ongoing basis, rather than as a one-off exercise. An important starting point is to develop a project information system to track
current resource allocations (both financial and human) and monitor shifts in resource allocation in accord with priorities. At this stage in the state of the art, economic analysis has not been shown to provide added value in selecting individual research projects.

**Monitoring and Evaluating Research Programs**

In this era of tight budgets, NARIs increasingly require performance monitoring and evaluation (M&E) systems that highlight research program impacts on national policy objectives and provide a basis for assessing progress and making needed adjustments to programs and policies. Through monitoring (the routine collection of data on program performance and program adjustments to identify problems) and evaluation (the analysis of monitoring data and system performance), NARI leaders and administrators can track research performance against plans and provide feedback for revising plans and strategies. M&E also provide the basis for measuring accomplishments and determining the success of program activities (Murphy 1993).

Progress toward the desired objectives is measured by indicators of program progress. Given the difficulties of measurement, it may not be possible to quantify some program outcomes, and qualitative or intangible indicators may have to be used. Table 3.2 provides a simple framework for thinking about an M&E system for agricultural research. Different types of indicators are applied at different frequencies at each level of a research system. Process indicators are largely for monitoring individual research projects and are the building blocks for monitoring overall progress in implementing an agreed-on research program. Process indicators should be quantified as far as possible. Good practice requires that research proposals include milestones that explicitly lay out specific progress in implementation. A relevant example is provided by the milestone indicators required in projects funded by the Research and Development Corporations in Australia.

Indicators of research outputs are used for both monitoring and evaluation. These may be measured at both the project and program level and will be different for basic and applied research. At the planning stage both research projects and research programs need to identify the expected outputs of the research as well as the intended users or beneficiaries of the research results.

Finally, impact indicators are largely used for evaluating research programs. Impact indicators are rarely practical or necessary at the project level, but should be applied to the program level at regular intervals, although, because of the long-run payoffs to much research, these intervals should usually not be less than five years. Impacts may be measured up to the system level, for example, through studying the economic returns to overall research investments (for example, econometric estimates of research impacts on changes in total factor productivity). Research funders sometimes call for even more in-depth evaluation of agricultural research on national policy objectives, such as food security or poverty alleviation. However, because of the multitude of factors influencing these objectives, this is difficult to do in practice (box 3.4).

In summary, the priority information requirements for M&E are as follows:

- Within a program, each project proposal should include a few simple monitorable milestones that quantify implementation progress as well as progress in achieving outputs. Progress against these milestones can then be measured in annual progress reports, perhaps supplemented by a very brief six-month report.
- At the program or institute level, each program should define long-run strategies and a five-year work plan that provides measurable indicators of implementation of the research program and of research outputs. Performance against these indicators can then be measured annually as part of the reporting requirements for project and program leaders.
- Regularly—about once every five years—each program should have a comprehen-
Table 3.2  Summary of monitoring and evaluation indicators and their implementation in agricultural research

<table>
<thead>
<tr>
<th>Type of indicator</th>
<th>Examples</th>
<th>Level at which applied</th>
<th>Frequency of implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process indicators for monitoring implementation performance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inputs</td>
<td>Funds expended, scientist time used</td>
<td>Project level, with aggregation to programs, institutes, and systems</td>
<td>Annually, with six-month progress updates</td>
</tr>
<tr>
<td>Outputs</td>
<td>Trials conducted, crosses made, surveys completed, varieties and other technologies developed, and recommendations made</td>
<td>Project level, with aggregation to programs, institutes, and systems</td>
<td>Annually, with six-month progress update</td>
</tr>
<tr>
<td>Impact indicators for monitoring and evaluating research</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Research outcomes (for monitoring and evaluation)</td>
<td>Applied research: Technology adoption rates and publications</td>
<td>Project level and program level, with aggregation to institutes and systems</td>
<td>On completion of a project (for example, after three years)</td>
</tr>
<tr>
<td></td>
<td>Basic and strategic research: New research methods, tools, techniques, hypotheses supported or rejected, and publications</td>
<td></td>
<td>Annually at the program level (for example, annual report)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>More in-depth at fixed intervals (for example, external reviews of programs)</td>
</tr>
<tr>
<td>Research impacts (for evaluation)</td>
<td>Applied research: Yield and production increases, cost reductions, economic return on research investment, impact on total factor productivity</td>
<td>Program, institute, and system levels</td>
<td>Once every five years for each program</td>
</tr>
<tr>
<td></td>
<td>Basic and strategic research: Use of new knowledge to increase the efficiency and efficacy of applied research</td>
<td></td>
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</tbody>
</table>

All research organizations must have an institutional capacity for M&E and for feeding the results back into decisionmaking. Building such a capacity requires only a modest investment and should be a priority for NARIs. The major problem in M&E systems for research has been the tendency to collect too much information in a highly centralized and bureaucratic manner. To date, there are few examples of good practice in this area, but the key elements of successful institutional capacity appear to be:

- Designing a simple system that minimizes data collection to a few critical variables
- Using a variety of mechanisms besides quantitative indicators as an integral part of M&E. These include planning and reporting workshops, field visits, external technical reviews of research programs, and regular visits to observe laboratories and experiments
- Decentralizing the implementation as far as possible. For example, project monitoring should be decentralized to program or subprogram leaders.
Box 3.4 Agricultural research and poverty reduction

Agricultural research is increasingly called upon to address equity issues, especially poverty reduction. This might be done through targeting research to regions and commodities important to the poor, or through developing technologies that favor the poor—especially labor-intensive technologies. However, the direct link between agricultural research and poverty reduction is complex. Research that generates broad-based productivity increases is one of the most effective means of reducing poverty through rural employment and income generation. One major impact of agricultural research is increased availability and lower prices for food, this is especially beneficial to the poor, who spend a large share of their income on food. The main emphasis in agricultural research systems should be on broad-based productivity enhancement in general. As a secondary consideration, research orientation can be modified by choosing particular regions or commodities that offer strong prospects of direct and sustainable pro-poor improvements, including research on staple foods consumed by the poor. Research may also directly address particular needs of women or disadvantaged groups.

In many cases policymakers and donors call for more research on marginal areas as a way of reducing poverty and arresting resource degradation. While this may be appropriate, the situation is usually much more complex. In some of the most difficult areas, the rate of gain from improved technology may be very slow. Providing infrastructure, education and nonfarm opportunities may bring earlier, greater and more sustainable benefit (to both poverty alleviation and conservation of natural resources) than is possible with agricultural intensification in many areas that have very high production risks and/or a fragile resource base. (Of course, research may well be a priority for such areas for reasons other than production intensification.) Finally, there are often substantial spillover benefits from productivity gains in favored areas through the operation of labor markets (that is, migration from marginal areas) and food markets (that is, lowered cost of food) (Renkow 1993; David and Otsuka 1994).

- Establishing a very small unit to promote M&E, provide training and develop standards, but undertake M&E only at the macro level
- Ensuring that there are mechanisms for research managers to receive timely information from the M&E system and take corrective actions
- Contracting some M&E activities, especially impact studies, to independent agencies or individuals.

Upgrading Human Resources Management

Ultimately, good research depends on the quality of human resources of the NARIs. Probably the most important element in building NARI capacity is to strengthen the management of the human resource base (Eicher 1990). Evidence that the quality of the human resource base may be declining in some research systems is cause for alarm.

Human Resource Management and Development

Problems with human resource management in NARIs can be grouped into three sets of interrelated issues: administration, incentives, and training. Administrative problems center around the problem of maintaining a productive scientific environment that encourages scientists in innovation and independent thought and initiative. Management approaches must be more conducive to such an institutional environment than are the hierarchical structures found in many institutions (Grindle 1997). Lack of development of a “science culture” discourages inquiry. In some systems few scientists are given real opportunities beyond their graduate studies to seriously practice science. Scientists are often frustrated by bureaucratic requirements established to prevent real or perceived abuses (for example, numerous signatures to authorize small purchases, onerous restrictions on the use of vehicles, or inability...
to obtain approvals for travel to international meetings.

There are no easy solutions to these problems, although autonomy from civil service rules is often sought by research institutions to provide needed management flexibility. Management reviews of institutions by outside experts or management firms can also help to identify bureaucratic bottlenecks and establish the need for training in research management.

The second key element in human resources management is an incentive system to encourage and reward researchers. Most NARIs still follow rigid civil service rules, which evaluate and reward researchers on seniority rather than merit and which do not require accountability from scientists and research managers. Few research institutions have good mechanisms for personnel evaluation, whether measured in research outputs or the adoption of these outputs by farmers and other clients. Scientists generally assert that they want merit-based incentive systems, but in practice frequently appear more comfortable with traditional systems based on job security and equal pay for all. Politics and economic realities often thwart any move to establish special salary schedules for researchers. Civil service rules, labor laws, and local attitudes limit flexibility for introducing performance-based incentives, and for dealing with poor performers.

Some of the most effective incentives to encourage good research can be nonmonetary and can include altruistic motivation; professional recognition by peers; or the satisfaction of scientific interest and curiosity. Nonetheless, NARIs need to continue to work to provide researchers with adequate, competitive salaries and other incentives to reward output. Management tools that can increase the effectiveness of human resource use include the following:

- Revamping performance appraisal and promotion systems. Research institutions need regular staff appraisal systems that recognize merit and give research scientists the opportunity for salaries, benefits, and prestige equivalent to those enjoyed by managers and administrators. Such arrangements are sometimes known as science-service schemes and are widely in place in industrialized countries.
- Putting emphasis on professional development of young scientists, including mentoring by leading researchers.
- Decentralizing budgets and project management to individual scientists. Management skills—learned through long experience—can be fostered by providing independence to scientists, once priorities are agreed upon and there is an adequate monitoring and evaluation process in place to ensure accountability. One way to encourage independence and research entrepreneurship is through competitive grants awarded to individual scientists or teams, rather than to institutions.
- Developing opportunities for consultancies by scientists to boost earnings and obtain wider professional experience. A sensible balance is required if institutional productivity is to be significantly and sustainably boosted. Such consultancies can be efficient vehicles for transfers of technologies (and even policies).
- Providing funding for sabbaticals, external travel, training, and greater interaction with the international scientific community to overcome the intellectual in-breeding common in many institutions.

Third, training will continue to be important for NARIs to maintain their human resource base for productive and sustainable research programs. Future emphasis will be on training for replacement staff and for upgrading skills to enable researchers to stay current in their disciplines and in emerging fields, such as biotechnology, communications technologies, and systems modeling. Meeting the costs of even modest foreign training programs will be an issue for many countries, and the development of local training capacities will be essential to system sustainability.
Research Program Leadership and Management

Improved leadership and sound management are key requirements for effective research institutions (Rukuni 1996; Nickel 1989). Leadership gives direction to an institution and its programs, motivates staff, and represents the institution with outside stakeholders. Sound management ensures that what is done is done efficiently—planning, conducting research, procurement, and reporting.

It is not always clear what constitutes good leadership and good management; nor is it clear what can be done when these are lacking. Changing leadership may be the only option, but even this carries no guarantee. In fact, suspicions of political motivation in change of leadership, long-term power struggles, long vacancies in key positions, or frequent changes in leadership positions may worsen a bad situation.

Few are truly born leaders, and leadership and management skill training can be important to research systems. For some, the major needs will be in human resource management and development. For others, training priorities may be in strategic planning, project planning, proposal writing and project management, or financial management. Unfortunately, this training is often less valued than technical training and may be considered by potential trainees as an admission of weakness. NARIs need to institute regular management training and leadership development programs as an integral part of human resources development.

Although training is important in developing leadership skills, it is also essential to ensure that the right people get appointed to top positions. Transparent and open recruitment processes have to be in place to appoint research leaders and senior managers. This is often difficult to carry out under standard civil service rules, and progress in achieving institutional autonomy may be part of the solution to the leadership problem.

Downsizing and Consolidation

Downsizing through reducing and consolidating research infrastructure and staff is one potential solution to the problems of low scientific salaries and acute scarcity of operating costs, provided that budget savings are used for these purposes. Some argue that downsizing is inconsistent with the findings of high returns to investment in agricultural research, implying that underinvestment in agricultural research must be prevalent. However, downsizing relates specifically to staff numbers and infrastructure, rather than to budgets. The staff targeted are generally not senior scientific staff, but support staff, who constitute a high proportion of total staff in many NARIs and who are increasingly becoming redundant because of improvements in office technology, laboratory procedures, or mechanized experiment station operations. In some cases (for example in much of the former Soviet Union), national systems have expanded to a size well beyond national needs and affordability and, therefore, a reduction in scientific staff will also be needed. Having a personnel monitoring system that permits ready identification of nonperformers is a minimal requirement for rational decision making in this regard.

Even where the returns to agricultural research are high in the aggregate, there may be good opportunities for reductions in specific programs. It is not difficult to find research programs that have been unproductive for many years and that merit hard scrutiny. If there is an alternative supplier (for example, in the private sector or abroad), the foregone returns from eliminating the program may be quite small. Finally, there is frequent overlap and duplication in research programs, or programs that target small areas or crops of limited significance. Recent work suggests that many of these programs are inefficient users of valuable research resources (Maredia and Byerlee 1996; Traxler, Byerlee; Jain 1996). In most NARIs it is not difficult to find programs whose marginal contribution is small.
Consolidating research infrastructure is another aspect of downsizing. Although there has always been recognition of the need for a "critical mass" of scientists in a research program, there have often been political or donor-induced drives to open new research stations, programs, or laboratories. NARI expansion has left many countries with more stations, field offices, and laboratories than they can maintain. Station or program consolidation will then usually be part of staffing reductions.

There are efficiency arguments for considering downsizing as an option in many NARIs. To avoid irreparable damage to staff morale, the downsizing process should be as transparent as possible, and be conducted within a well-defined NARI strategy and research plan. It is critical that research managers have agreement from the highest levels that budget savings from downsizing will be retained by the research institute to improve operating budgets and salaries of remaining staff. Donors can help this process by providing downsizing conditionality and the funds needed to compensate departing staff and to improve the working conditions of those who remain.

Improving Client Orientation and Technology Transfer in National Agricultural Research Institutes

Strategies to involve users in the research process include: informal research-farmer collaboration, such as in farming systems research; interaction with farmer organizations; empowerment of farmers through farmer representation in research governance; farmer-financing of research and participation in decisions on the allocation of research funds; closer research-extension linkages; and linkages with private industry associations.

Improving Client Orientation of Research Institutions

From the 1970s there was a growing awareness that much agricultural research in NARIs was not relevant to the needs of most farmers, especially small-scale farmers and farmers in marginal areas. Failure to involve the main users in the research process led to several inefficiencies: failure to adequately identify problems and priority technology needs, exclusion of an important source of innovations—the farmers themselves and their indigenous knowledge; inability to access farmer funding for research; and delays in the dissemination of research results.

This led to a strong emphasis on farming systems and on-farm research (FSR) during the 1980s, much of it with World Bank support. The major contribution of this movement was to provide methods for diagnosing farmers' problems, setting research priorities to address those problems, and screening potential technologies for their relevance to small-scale farmers' circumstances (Merrill-Sands and Collion 1992). In recent years more participatory methods have been developed that seek to directly involve farmers in the design and execution of experiments (Tripp 1989; Okali, Sumberg, and Farrington 1996; Ashby and others 1995). All this has, of course, implied considerable investment of researchers' time in working directly with farmers.

Reviews of the impact of these methods concluded that they were only partially successful, as measured by more rapid adoption of technologies by farmers (Merrill-Sands and others 1990; Tripp and others 1990). Difficulties often arose from treating FSR as a separate discipline and creating new units or departments to conduct FSR rather than trying to introduce a farming systems perspective throughout the research system through active collaboration among existing disciplines (especially among technical and social scientists) and with farmers. FSR approaches cannot and should not be a substitute for strong disciplinary capacity. Other problems with FSR have included:

- Lack of technologies on the shelf to adopt because of weak commodity and disciplinary programs
- Poor links between research, extension, and policy, so that research recommendations often did not reach farmers, or were
not adopted because of lack of access to appropriate inputs.11

- Difficulties in feeding back information from farmers to define priorities for applied and strategic research conducted on the experiment station.

Merrill-Sands and Collion (1992) aptly summarize the main outcome of this movement as leading to "client-oriented researchers but not to client-oriented research organizations." FSR perspectives and methods are important for conducting effective research programs, especially for small-farm agriculture, and continuing efforts are needed to strengthen farming systems perspectives and methods in agricultural research programs. FSR and community participatory approaches are especially relevant to natural resources management and eco-regional research. Farming systems approaches also need to be incorporated into university degree programs to provide future researchers and technical staff with a better understanding of how and why farmers do what they do, and with appropriate tools for working with farmers.

Greater client orientation in research systems should result from direct influence of clients on the content of research. Farmers and their organizations can exert pressure in several ways:

- Through the political system, by appropriation of government revenues for agricultural research. This assumes that the interests of farmers' and other clients of the research system are broadly represented in the political process.

- Through the participation of representatives of farmers organizations (general or commodity-specific) on governing boards and research advisory and review committees of research institutions. Farmers included on such boards should represent the spectrum of intended clients of the research system. In some cases it may be appropriate to include representatives of processors, marketing, or consumers to represent post-harvest and consumer interests.

- Through contributions by farmers to the funding of agricultural research, accompanied by mechanisms by which farmers influence how these funds are spent.

- Through participation of farmers in the execution of research, especially adaptive research designed and implemented by farmers themselves (box 3.5).

- Through participation of farmers or farmer organizations in M&E of research, especially applied and adaptive research, where farmer feedback and technology use can be part of performance evaluation.

Although there is a high potential for farmer organizations to define the research agenda, effective organizations usually exist for only a limited number of commercial and export-oriented crops. The development of farmer organizations with necessary technical, managerial and political skills to represent the bulk of small-scale farmers will continue to be a challenging task (box 3.6) (Eponou 1996; Collion and Rondot 1997). In addition, there are other limitations on farmer input and direction of research. First, farmers lack knowledge of some new technologies and options. They tend to seek incremental changes to known production systems and may oppose broader changes (for example, early resistance to adoption of hybrid maize). Second, farmers may take a short term perspective and limit support to basic or strategic research with longer term payoffs.

There are, of course, other clients for the NARSs besides farmers (box 3.7). Large agribusiness firms may have their own research programs and become partners rather than strictly clients for public sector research. Even in such cases private sector firms usually rely on public sector research institutions for more basic research and for some technical backstopping of their research programs. In any event, identifying the technology needs of agribusiness requires attention to clients other than the farmer.

The less obvious client for agricultural research programs is the consumer. Many consumers' demands and interests are reflected in the market (for example, price premiums for grain quality) and routine collection of such
Box 3.5 Farmer-run research: Experience with the Comité de Investigación Agropecuaria Local

Moving from the traditional, station-based research system to a participatory, demand-driven approach of on-farm testing presents potential problems. Off-farm research can be costly in researcher time and operating costs. Even the best-intentioned efforts may fail to draw farmers into a participatory research process or provide adequate supervision for dispersed field trials. Turning responsibility for on-farm testing over to farmers is an attractive alternative being tested by CIAT in several NARSs of Latin America (Ashby and others 1995).

Under the Comités Investigación Agropecuaria Local (CIAL) program, begun in 1990, an institution with interest in technology dissemination (usually a state agency, NGO, or cooperative) facilitates a meeting in which a community analyzes potential needs for local technology testing. If the community is interested in undertaking local research, it selects a four-member Committee (the CIAL) from the community to coordinate the research work. Outside technical staff from the organizing institution assist in planning and analysis of research trials and a paraprofessional (a CIAL-experienced farmer) monitors and advises on the research. Technical staff visit 2–3 times per season after the first 2–3 seasons.

CIALs operate with a small CIAL Fund (US$50 per community) to cover the risks of crop failure or to subsidize the costs of trials. These CIAL funds have been consolidated into a corporation at the national level, but each CIAL manages its own fund. The funds, like the whole program, are “owned” by the community and managed by the Committee.

By 1995 55 CIALs had been established in Colombia and others were formed in Bolivia, Ecuador, Honduras, and Peru. Communities have been very responsive in taking on local research responsibilities. After two seasons CIALs are able to take on almost all responsibility for on-farm experiments and paraprofessionals can provide almost all training and monitoring for the program. Research quality has been good, with 75 percent (of 273 plots) statistically analyzable. Six CIALs have evolved into commercial seed enterprises.

1. Comités Investigación Agropecuaria Local are local agricultural research committees.

Market information can be important to research priority setting. Other consumer needs that are not as easily detected include issues of food safety, nutritional quality, and environmental interests. In some countries consumer advocacy groups and other NGOs are active and can provide an interface between the research system and the consumer. In such cases, or where markets do not function well, consumer surveys can be a valuable input into research decisionmaking, especially for gauging the strength of preferences about particular quality traits (Ricks 1997b; Rubey, Ward, and Tschirley 1997). Consumer concerns, especially food safety issues, such as pesticide residues, will be increasingly important in setting the research agenda.

A NARS’s client base is varied and not well organized. Building a farming systems perspective into agricultural research systems has contributed to the relevance of research to the main clients, the small-scale farmer. However, in future more attention must be given to empowering farmers to provide direct input into the research agenda. Research systems will also increasingly need to recognize other clients, such as agribusiness and consumers. This implies that institutional structures for public research systems must:

- Develop incentive mechanisms for scientists to be rewarded for work that makes explicit efforts to diagnose and solve real

Box 3.6 Links to farmers’ organizations

A recent study of linkages between research and farmer organizations in Burkina Faso, Ghana, and Kenya (Eponou 1996) found that most are ineffective. Farmer organizations may not consider linkages to technology programs as an organizational objective, or may be unaware of the possibility of a linkage, or may not see a possible benefit. Research institutions have only recently recognized farmer organizations in the research process; may still be unconvinced of potential benefits; and are hindered by existing operational policies. The study concluded that more effective linkage mechanisms are needed between farmer organizations and research, and that the power of farmer organizations must be increased to strengthen their influence in the relationship.
**Box 3.7 Improved research-extension linkages: The case of Ghana**

Research-extension linkages in Ghana have always been complicated by the fact that research is in the Ministry of Science and Technology and extension in the Ministry of Food and Agriculture. But recent Bank support to both research and extension has provided an opportunity to strengthen research-extension linkages. Research-Extension Liaison Committees (RELCs) have been formed in each major agroecological zone to jointly plan research and extension priorities and to promote joint training sessions, field visits, workshops, field days, and on-farm trials.

These RELCs sponsor a series of annual planning meetings and joint activities at multiple levels in the system. Wherever possible private agribusiness, farmers, and NGOs are invited to join. The annual planning cycle includes:

- Participatory rural appraisals (PRAs) of farmer problems at the district level. Extensionists, farmers, and researchers take part in these appraisals, which are used to draw up district extension plans for the year.
- Regional meetings for each agroecological zone to consider results from the district PRAs. Extensionists, researchers, and farmers all participate in these meetings, and assign identified problems to research and extension. The regional meetings also identify extension training needs and plan joint research-extension workshops and monitoring tours for the year.
- A national meeting of research institutes and programs—with extension participation—develops the research program plans for the coming year.

Although the system is still in its early stages, the RELCs have clearly led to greater collaboration and communication between research and extension. Further evolution of the system must address issues of reducing the number of meetings and joint activities, which are costly and time-consuming, and improving monitoring to ensure that planned activities are carried out.

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Problems of farmers and other clients and that achieves on-the-ground results

- Develop mechanisms for ensuring a real voice by users in setting the research agenda. The appropriate choice of mechanism is very situation-specific, depending on the type of user and the type and level of research
- Involve farmers in decisions on allocating public funds for research, and link farmer financing of research to farmer empowerment in research decisionmaking.

**Enhancing Technology Transfer**

Technology transfer or dissemination has been a weak link in most NARSs. The reviews of World Bank experience in research have all identified this as a limitation on realizing the benefits of research. In the past this has been associated with weak research-extension linkages: nowadays, however, technology transfer is being realized through other mechanisms, including diverse types of NGOs and the private sector. Strategies to enhance technology transfer will increasingly require that research institutes link with this wider range of actors.

Research-extension linkages remain a critical weakness in many countries (Merrill-Sands and others 1990; Spurling and others 1992; Antholt 1994). In theory, the dividing line between research and extension blurs in the stages of adaptive research and verification of technology. As agriculture becomes more knowledge-intensive, these linkages will be even more critical because research must generate greater amounts of (and better quality) information to pass on to farmers.

Institutional solutions to the research-extension gap, such as research-extension liaison persons, high-level research-extension coordinating committees, and other measures designed to strengthen linkages, have rarely succeeded. The reasons for this failure include the institutional separation of research and extension, the fact that many research recommendations are not relevant to farmers' circumstances, the tendency for researchers to see their job as done when the technology is developed, rather than when it is adopted, and the low professional preparation and status of...
extension staff, which limit their ability to feed information back to the research system.

The World Bank has recently tried to solve these difficulties by designing joint research and extension projects, sometimes labeled "technology" or "agricultural services" projects. This will only succeed, however, if the design of these projects is truly a joint activity and not simply the sum of two components. In the long run a truly decentralized extension system with real accountability to farmers is likely to be the best means of allowing extension to place demands on the research system. In the short run some institutional means that have been useful in strengthening research-extension links include:

- Joint operation of on-farm adaptive research with strong involvement of farmers, including the joint conduct of diagnostic surveys and on-farm experiments
- Joint formulation of technological recommendations and extension priorities (box 3.7)
- Introduction of reward systems based on farmer adoption of technology for research and extension staff
- Bureaucratic mergers that simplify life for all concerned.

Even these short-run solutions are unlikely to succeed unless a real effort is made to ensure that farmers themselves are at the center of efforts to reinforce research-extension linkages. Reward systems for research and extension must be firmly based on the involvement of farmers and performance on the ground. Experience shows that effective research-extension linkages are better promoted by providing incentives and rewards to both parties to solve farmer problems, than by institutional solutions in the form of new committees or specially created positions. With the essential harmony of interests, there will be real pressure to work together.

Stronger links to NGOs offer another means of strengthening technology transfer. NGOs are increasing rapidly and, by one estimate, 15 percent of farmers in Latin America (primarily small-scale farmers) now receive some services from NGOs (Kaimowitz 1993). NGOs have considerable potential to supplement public extension services that are under budget pressures and to serve areas and farmers not covered by the public system.

The strong rural presence, dedication, and commitment to impact on the poor, common to many NGOs, makes them potentially valuable partners in technology-transfer programs. NGOs also have some comparative advantage in adaptive research, since they tend to emphasize participatory methods and have the flexibility to undertake and integrate activities, especially in resource conservation where community decisions may be required. But most NGOs have little experience in conducting research and often lack technical expertise. Some examples of successful research program-NGO collaboration are available from Central America, where the adoption of resource-conserving technologies has been promoted by NGOs with close ties to these research programs (for example, Buckles and Erenstein 1996).

Community-based organizations and farmer organizations are specialized types of NGOs formed by rural people—the major users of the research system's products. Community-based organizations are now becoming more involved with natural resource management activities (for example, irrigation management and community-based forest resource use), many of which must be undertaken by the community to be effective. These rural organizations can be important users of (or conduits for) technical information from research-extension systems to their members.

The links between research and NGOs are in their early stages and much remains to be learned about how to effectively and sustainably integrate NGOs into the process of technology transfer. In the future, NARS strategies will need to consider a significant involvement of NGOs, especially community and farmers organizations, in on-farm adaptive research, community-based resource management, and in providing a conduit for feedback from users to research priority setting and design. To fully use this synergy, research institutions, espe-
cially regional research stations, must develop institutional mechanisms for establishing partnerships with NGOs and incorporating them into decisionmaking.

The private sector, including input dealers, agribusiness enterprises, and private consultants, will become increasingly important in technology transfer, implying the potential for the development of NARI-private sector partnerships. Even large agribusiness firms often find it cost effective to seek technical support for local adaptation and transfer from the public sector. To promote competitiveness and benefits from such enterprises, NARIs need to ensure that organizationally there is a window or point of contact for private agribusiness to seek technical information and support from the NARI. Such a contact point may serve to coordinate assistance from various units in the government (research, extension, and quarantine service) and can help to feed private sector needs back into research planning. This will require increased capacity for post-harvest handling and processing technologies for non-traditional crops, with much of this work done under cost-recovery mechanisms. The public sector may also work with private companies to disseminate technical information from the public research system; for example, in using chemical companies to disseminate some IPM technologies.

Finally, government policies are often critical to farmers' ability to adopt and profit from new technologies and research programs must recognize policy constraints to technology adoption and provide input to policy formulation (box 3.8).

Notes

1. Although this section focuses on the national research institutes, which exist in most countries, many of the principles articulated here are equally relevant to universities and other public sector research organizations.


3. For example, India spends about 0.26 percent of agricultural GDP on research (Singh, Pal, and Jha 1997) while it spends the equivalent of 7 percent of agricultural GDP on input subsidies alone (Gulati and Sharma 1995). In Zimbabwe in many years expenditure on

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Box 3.8 Serving the “policy client”

The agricultural policy environment has major implications for technology transfer, and NARIs are well-placed to provide information and analysis to change the policy environment. Socioeconomic research often makes the most important and direct contribution to policymakers, but biological research also provides valuable inputs. During the research process much information is generated that could be useful in policy formulation (for example, input response data, potential of new crops, and factors affecting the efficiency of input and resource use at the farm level). Experience has shown that providing this type of information can help shape policies and facilitate the adoption of technologies (for example, Martinez and Sain 1991) and NARIs should attempt to package and report such information in a form useful to policymakers. There is a critical need for NARIs to increase their input to the policy process. Ultimately, it is in the interests of NARIs to increase their involvement with policy issues, as judgment of NARI effectiveness will be based on the adoption and impact of new technologies, which are highly dependent on the policy environment.

The policy environment also affects investment in research; there is little incentive to invest in technology generation when the results are unlikely to be adopted or benefits generated. However, the policy environment for future adoption of any research result is highly uncertain and the long time lag in producing useful research results provides one rationalization for research investment even in a poor policy environment. With an unfavorable policy environment, investment in research should be continued in specific highly focused areas, such as for technologies whose adoption success is less sensitive to the policy environment (for example, new varieties), long-term research that requires continuity (for example, maintaining genetic resistance to diseases), and research on high-priority issues such as emerging pest problems. Meanwhile research on impacts of technology development can provide important input to government policy decisions on investment in research.
research is dwarfed by support to the grain marketing corporation.

4. Levies also include check-offs (as used in the United States). Such research financing mechanisms vary from what is essentially an additional tax to finance government research programs to funds collected (with government assistance) on behalf of producers themselves for use by a nongovernmental producer organization to fund research and promotional activities (Gilles 1997).

5. In this case the method has the advantage that the levy is paid in proportion to farmers' marketed surplus and is likely to be strongly progressive in terms of farmers' incomes.

6. The term "donor" is used here to include international lending agencies.

7. At first this support was for incremental operating costs associated with capital development, with the expectation that this budget would be assumed by the government at the end of the project. More recently, there have been many examples of donor support to operating budgets that are independent of capital development.

8. Creation of autonomous research corporations for supplying research products may also widen the institutional and cultural gap between research and extension and lead to difficulties in disseminating technology. However, this is becoming less of a problem as technology dissemination is increasingly being managed through diverse suppliers, and extension systems themselves are being privatized and decentralized.

9. Donors have been unwilling or unable to adjust their priorities to conform to the new master plan. This may be especially problematic when one donor champions the development of a research plan, which places a low priority on topics or regions in which other donors have on-going activities.

10. Linking results from the priority-setting work to the allocation of competitive grants is one way to quickly shift resource allocation in line with identified priorities.

11. There has always been a tension in farming systems research (FSR) especially in Africa, between developing technologies for the current situation of farmers, often characterized by limited access to inputs and credit, and using the results of FSR to influence the policy agenda. Much of this tension relates to the debate between low-input and high-input strategies for agricultural intensification. It is now apparent that there is a middle ground, which recognizes that some external inputs, especially fertilizer, will be required.

12. One response to the problem of technology support for agribusiness has been project support for agribusiness development (for example, through the USAID). Such projects have followed varied strategies of institutional development, market development, and enterprise support, but have typically included consideration for technology support (Kumar 1995).
CHAPTER 4

The World Bank’s Role in Strengthening National Research Systems

It is vital that the Bank maintain its commitment to developing national agricultural research systems. The Bank is by far the largest donor to the sector, and other traditional bilateral donors are reducing their funding for agricultural technology programs. The development and dissemination of improved agricultural technologies will be critical to meeting the challenge that the Bank has laid out in its Action Plan for the rural sector to reduce poverty, improve food security, and better manage natural resources (World Bank 1997a). Such a transformation must depend on a more productive and sustainable agriculture, which requires a continuous flow of new technologies and improved management techniques.

The discussion of issues facing the research subsector repeatedly identified this subsector as having changing needs and opportunities. These have significant implications for Bank support to national agricultural research systems. To some extent, the conventional wisdom that national agricultural research systems (NARSs) have become stronger is now questioned and it is realized that much of past capacity development is not sustainable. It is evident that the capacity of many NARSs has been eroded by the current funding crisis and by institutional inertia. Given the level of past investments and the emerging challenges to agricultural research, the Bank should strongly commit to the development of the NARSs. This final section summarizes key elements in current Bank strategies to support agricultural research.

Evolution of Bank Support to Research

From 1981 to 1996 the Bank financed 458 projects with agricultural research components in 91 countries. Of these projects 50 were free-standing research projects and 408 broader sector projects with research components. Research funding under these projects totaled US$3.87 billion. In recent years annual commitments have averaged about $200 million (table 4.1 and Annex 2). The Bank’s lending for agricultural research now accounts for a large share of all external support for agricultural research in developing countries. By the end of 1996 91 countries had received assistance for agricultural research under the lending program. Many countries had sequential agricultural research projects: in some cases the Bank has supported agricultural research continuously for 15 years or longer.

Bank Lending to Agricultural Research

Both the research and extension shares of total Bank lending for the agricultural sector increased significantly since the late 1970s and
especially since the mid-1980s (figure 4.1). This is a function of both a modest increase in funding for research and a decrease in the total funding for the agricultural sector.

Research project financing has been reasonably well distributed geographically (figure 4.2) with Africa, Latin America, and East and South Asia each receiving between 29 and 31 percent of the total funding from 1981 to 1996. Europe and Central Asia and West Asia/North Africa each received only 5 percent of the total. Over this period there has been a major geographical shift in the share of lending from Latin America and East Asia to Africa and South Asia (table 4.2).

### Bank Policies and Strategies

The World Bank developed its only formal policy statement on agricultural research in 1980 (World Bank 1980). This policy clearly emphasized expansion of the NARSs, with particular emphasis on the NARls. The policy identified as a long-term objective the increase of public expenditure on agricultural research from the 1980 level of less than 0.5 percent of agricultural GDP (AgGDP) to 2.0 percent. This expanded program of research envisioned a corresponding increase of 9,000 additional trained scientists.

The Bank’s strategy, outlined in 1980, was to increase Bank lending for research programs (at the expense of lending for extension) with emphasis on food staples for low-income con-
Figure 4.2 Geographic distribution of World Bank agricultural research funding between 1981 and 1996

The strategy also provided for support to more basic and strategic research at the IARCs and strengthening NARSs in fisheries research, tropical soils management, irrigation and water management, pest management, nitrogen fixation, photosynthesis, and genetic manipulation. The 1980 policy also laid out operational strategies for strengthening agricultural research management and incentives through project lending (table 4.3). The growing importance of these operational strategies was reflected in the number of agreements and conditionalities on organization, structure and management attached to project lending in recent years. Most of these operational strategies still guide support to NARIs today.

Since approval of the 1980 agricultural research policy paper there have been several internal reviews of Bank experience with agricultural research projects (World Bank 1983; Pritchard 1990). These reviews largely confirmed the directions set out in the policy guidelines and noted significant successes in institution building, although the challenges associated with developing capacity for priority-setting, research-extension linkages, budgetary support and incentives for scientists, and research monitoring and evaluation continued.Recommendations from the various reviews of the Bank research project portfolio are summarized in annex 1.

In 1996 the Operations and Evaluation Department (OED) of the Bank did a comprehensive review of completed agricultural research projects. This was more guarded in its conclusions. It found that, although Bank intervention in agricultural research has had significant positive impacts, serious deficiencies persist in sustaining research institutions and in establishing institutional capacity in research planning, priority setting, and evaluation. The review noted particular concern with the sustainability of research funding, especially the weak capacity for policy and economic analysis in most NARSs, and strongly recommended the wider use of economic analysis to guide research planning efforts and increase research efficiency. The major recommendations of the review are given in box 4.1.

In the 1990s the Bank responded to the new realities of NARSs and significantly departed from certain aspects of the 1980 policy guide-

Table 4.2 Regional shares of world bank loans for agricultural research

<table>
<thead>
<tr>
<th>Region</th>
<th>1981–84</th>
<th>1993–96</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>6</td>
<td>50</td>
</tr>
<tr>
<td>Latin America</td>
<td>36</td>
<td>8</td>
</tr>
<tr>
<td>South Asia</td>
<td>15</td>
<td>27</td>
</tr>
<tr>
<td>Southeast and East Asia</td>
<td>39</td>
<td>9</td>
</tr>
<tr>
<td>West Asia/North Africa and Europe/Central Asia</td>
<td>4</td>
<td>6</td>
</tr>
</tbody>
</table>

Note: Percentages are based on 127 projects in 1981–84 and 103 in 1993–96.
Table 4.3  List of operational strategies identified in 1980 World Bank policy guidelines

<table>
<thead>
<tr>
<th>Theme</th>
<th>Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning and priority setting</td>
<td>• Encourage preparation of national research plans and develop capacity in planning and managing research.</td>
</tr>
<tr>
<td></td>
<td>• Review overall agricultural sector policy in relation to incentives for technology adoption.</td>
</tr>
<tr>
<td>Financing</td>
<td>• Provide financial support for long-term development of research programs</td>
</tr>
<tr>
<td>Review and evaluation</td>
<td>• Institute periodic internal and external reviews of research programs</td>
</tr>
<tr>
<td></td>
<td>• Encourage research organizations to establish effective monitoring and evaluation systems to assess impacts.</td>
</tr>
<tr>
<td>Incentives</td>
<td>• Ensure adequate incentives for researcher performance.</td>
</tr>
<tr>
<td>Linkages</td>
<td>• Design operational strategies to strengthen researcher-extension-farmer links</td>
</tr>
<tr>
<td>Training</td>
<td>• Incorporate both research management and technical specialization into training programs and link training to the needs of research plans.</td>
</tr>
</tbody>
</table>


lines. The emphasis now has shifted to a focus on quality dimensions of agricultural research, especially management, incentive systems, and accountability, with conscious efforts in most cases to avoid further creation or expansion of public research organizations. Downsizing and consolidation of research infrastructure is the order of the day. Table 4.4 shows how emphasis in Bank programs has changed in the past three years to emphasize these institutional and qualitative issues, while aspects such as master planning have been de-emphasized. In these institutional dimensions the Bank has probably had less success than with the quantitative dimensions of expanding the size of the system.

Overall, since 1980 agricultural research has been considered a priority in the Bank’s lending portfolio. The Bank has responded to the 1980 policy guidance and provided a commendable level of attention and support to agricultural research and development, although results may not have always been in line with expectations. A 1997 Bank review of “at-risk” projects indicated that the research project portfolio has performed relatively well, but

Box 4.1  Major recommendations of the Operations and Evaluation Department review of agricultural research projects

The 1996 Operations and Evaluation Department review made ten major recommendations for strengthening future lending to agricultural research:

1. Review the roles of the agricultural sector and agricultural research in Country Assistance Strategies (CASs)
2. Continue strong support for international, regional, and national agricultural research, but with comprehensive support for NARSs contingent on borrower commitment to sustainable funding for research and to sound research management principles
3. Provide limited research support combined with nonlending services to strengthen borrower commitment, when favorable sectoral or research policies are lacking
4. Foster external NARS linkages and Bank alliances with development partners to enhance the effectiveness of research programs
5. Encourage the use of economic analyses for borrowers to prioritize research activities and for the Bank to evaluate research programs ex-ante and ex-post
6. Use a core of specialized Bank staff to enhance support for research program development
7. Treat dissemination of research findings as an integral part of technology development
8. Design projects that develop NARS procedures to make research programs more relevant to clients’ needs
9. Include monitoring and evaluation systems as a mandatory element of Bank research projects
10. Include measures to enhance scientific rigor (training, technical assistance, external reviews, competitive grant funding, scientific networking, and institutional linkages) in all Bank-supported research projects.
Table 4.4  Trends in institutional issues emphasized in the current World Bank portfolio of research projects

<table>
<thead>
<tr>
<th>Issue</th>
<th>Percentage of projects approved by Board</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emphasis on institutional pluralism</td>
<td>50 86</td>
</tr>
<tr>
<td>Promotion of private-public interaction in research and development</td>
<td>12 71</td>
</tr>
<tr>
<td>Support for new funding sources</td>
<td>6 87</td>
</tr>
<tr>
<td>Support for competitive funding</td>
<td>12 86</td>
</tr>
<tr>
<td>Support for downsizing and consolidation</td>
<td>25 57</td>
</tr>
<tr>
<td>Involvement of farmers in research governance and funding</td>
<td>38 87</td>
</tr>
<tr>
<td>Development of master plans for national agricultural research institutes</td>
<td>50 14</td>
</tr>
</tbody>
</table>

Source: Based on a review of World Bank portfolios of research projects.

that there are some common problems in research projects (box 4.2).

The Bank has responded to the challenges of building effective NARS capacities in other ways. In 1985 the Bank with other donors initiated the Special Program for African Agricultural Research (SPAAR) to meet the special needs in African agricultural research (for example, uncoordinated donor programs and lack of local funding). SPAAR is helping to build consensus and cooperation to coordinate and focus donor support to NARSs. In 1994 the Bank established the Office for Agricultural Research and Extension (ESDAR), a multidonor forum to coordinate support to agricultural research and extension programs and create the linkages necessary for a more efficient and effective global agricultural research system (Petit and others 1996). The Bank, recognizing the strategic importance of international agricultural research for NARSs, has in recent years increased its support to the Consultative Group on International Agricultural Research.

**Key Elements of Current Bank Strategy**

The Bank and other donors have shifted emphasis of support for national agricultural research systems. The earlier focus on system expansion has given way to greater attention to management of resources within the research system. This emphasis will need to continue, but greater support will be required for policy reforms that enable NARSs to develop sustainable financing systems and that integrate international and national institutions into efficient research systems.

**Expanded Role for Policy Dialogue**

Recognizing the strategic issues now faced by NARSs, the Bank must expand support to policy

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**Box 4.2 Problems identified in a 1997 review of agricultural research projects**

In 1997, under the Portfolio Improvement Program, the Bank reviewed research and extension projects categorized as at risk of producing unsatisfactory outcomes. Common problems found were:

- Lack of a consensus in-country on a strategic vision for public sector research institutions and the evolution of the national agricultural research system (NARS)
- Ineffective national leadership for many research institutions, resulting in both internal management problems, as well as lack of political support, especially for funding research
- Difficulties in establishing institutional autonomy for research institutions because of lack of understanding of the special needs for research management, and lack of imagination in formulating the mandates and rules of business of the new organizations
- Inadequate attention to sustainable financing for research, especially for new research initiatives after project completion
- Weak monitoring and evaluation systems for both research programs and institutional changes.
Strengthening National Agricultural Research Systems and institutional change through economic and sector work and conditionality on loans. The accurate assessment of constraints, opportunities, and strategies for a national agricultural research system will be central to future economic and sector work. This process must be highly participatory to build borrower consensus on feasible policy options. Much discussion will be needed to change traditional attitudes and relationships within NARs and to build a country commitment to investment in agricultural research and institutional change appropriate to that country’s situation.

Economic and sector work should give particular attention to sustainable funding of agricultural research and to promotion of private R&D. Sustainable funding is best addressed in the Country Assistance Strategy (CAS) that is discussed with ministries of finance that have a major influence on the allocation of public funds. Such dialogue between the country and the Bank should explicitly identify the public-good component of agricultural research as the basis for public funding. Conditionality may be used selectively to influence borrowers’ research policies. Conditions may relate to restrictions on system expansion, promotion of regional coordination, and implementation of institutional and management reforms in NARs. These conditions must be used carefully, recognizing that project conditions are not a substitute for, or necessarily indicative of, borrower commitment; rather these should be seen as mutually-accepted guidelines for change developed through participatory processes. Where possible, conditionalities on research funding and institutional reform can be part of broader sector investment and adjustment loans whose success ultimately depend on availability of improved agricultural technologies, rather than as conditions specific to agricultural research projects.

Economic and sector work must also analyze policies and regulations that may be restricting private investment in R&D. In this it will be important to distinguish between policies and regulations that relate to public safety and the national interest versus those that are implemented to “protect” farmers or maintain public sector monopolies. Since private R&D investment is often made on the basis of regional markets, harmonization of policies at the regional (supra-national) level will often be more important than at the national level.

**Emphasis on Sustainable Funding**

Both Bank lending and nonlending work should give explicit attention to the level and long term sustainability of research funding. New investments in research capacity building must be conditioned on borrower commitment to sustainable financing (as in the Operations and Evaluation Department (OED) Report). The emphasis should be on mobilizing resources for support to research programs after completion of donor assistance. Bank support may include:

- Economic and sector work and associated policy dialogue that reviews the allocation of public funds to competing claims
- Support in Bank projects to sustainable funding mechanisms for a more regular and predictable level of financing for research programs, such as farmer financing, cost-recovery, and endowed research foundations
- Development of mechanisms for fostering public-private interaction in agricultural research, including the legal framework for establishing joint ventures
- Explicit analysis of sustainable research funding levels in preparation of projects for Bank support to ensure that research activities and infrastructure can be maintained after project completion
- Analysis of the research portfolio to clearly identify the public-good research activities, relative to those activities that could be undertaken by the private sector or other alternative suppliers.

**Renewed Attention to Universities and Human Resources Development**

Recent Bank projects have given more attention to the place of universities in executing
research, mainly as potential recipients of competitive research grant funding. In the future this focus must be broadened to strengthen university capacities to undertake research and to recognize the key task of universities in training the next generation of scientists. More scientists will have to undertake postgraduate degrees locally, and this will require a substantial upgrading of capacities in local universities. In some NARS that have already shifted to local training, this capacity has been eroded and it will require long-term support to revitalize the university system. The Bank has less experience in projects aimed at university capacity building and will need to begin cautiously and engage outside experts to help build such capacity.

Continuing Institutional and Policy Reforms in National Agricultural Research Institutes

While NARIs are no longer so central to efforts to strengthen agricultural research capacity, in most countries, the bulk of the human resources and research infrastructure is located in the NARI. So, continued efforts are required to strengthen the productivity and cost effectiveness of NARIs through a range of management and organizational reforms, including definition of mandate, diversification of funding sources, decentralization of some research activities, planning and priority setting, monitoring and evaluation, human resources development and management, and links to major clients. The institutional structure of NARIs in relation to civil service rules and the governance of the NARI will be major factors in implementing these reforms. Policy and institutional reform in the formerly centrally planned countries of Europe and Central Asia represent a special challenge with high priority (box 4.3).

Fostering Regional and Global Collaboration

The Bank needs new approaches to promote cost-effective regional research activities. Initially, the Bank can help build commitment by funding workshops and meetings to establish and define regional research activities. This may require special regional funds administered through Bank regional programs. Once a real commitment to regional activities has been established, support for regional activities could be included in country loans for agricultural research, with the NARs taking the lead in defining the priorities and activities for this support. The Bank is also leading efforts to facilitate more active participation of NARs in international agricultural research policy issues through the Global Forum on Agricultural Research (box 4.4).

Donor Coordination

Bilateral donors can provide complementary grant financing for training and technical assistance, which countries are often reluctant to fund from Bank loans. The complementarity of these inputs can be especially important in improving the quality of research and strengthening NARs linkages to the global research system. Donor inputs can also be an important complement to Bank work on diagnosing NAR constraints and developing system improvements through participatory processes. Donor coordination is the clear responsibility of NARS leaders, but the Bank, as the major lender for agricultural research, can encourage greater coordination of all donor investments and activities in agricultural research. The Bank's prominence in financing agricultural research and its recognized capabilities can help to convene donors and research agencies to a common purpose. Such coordination is most important at the country level, although regional and international coordination is also needed.

One good model of coordinated donor financing is the consolidated funding mechanism, whereby donors provide support for an agreed-upon national research plan. The Agricultural Research Funds (ARFs) in Kenya, Tanzania, and Zambia are a practical approach to a consolidated funding mechanism. These allow donor funds to be channeled (on a competitive or noncompetitive basis) to priority research activities. The ARF standardizes man-
Box 4.3 An emerging challenge: The national agricultural research systems of Eastern Europe and Central Asia

One of the emerging challenges for the Bank and for the global agricultural research community is that of revitalizing agricultural research in the countries of Eastern Europe and Central Asia. The agricultural research systems have not fared well during the transition to market economies. Many countries have major agricultural production potential and a solid scientific base. The research systems, however, have not made the transition to more market-driven systems. They are oversized and isolated from the world scientific community. With the drastic fall in funding, younger staff are abandoning the research institutions.

Integration of the research system of former East Germany, admittedly a special case, provides some insights. After reunification the number of scientists outside the universities is to be reduced by more than 80 percent (from 6,200 to 1,081) to bring it in line with the numbers in the West. Staff and institutions were shifted from centralized, science academies and ministries to regional centers more closely linked to producer needs. Many staff left voluntarily and joined the private sector; some institutes were privatized or simply ceased to function. For other countries of the region the reform process is taking much longer. Governments of the region must first recognize the importance of restructuring their agricultural technology innovation systems to support market-based economy and a growing private sector. With demonstrated commitment to reform, the Bank and other donors may initiate support vital to the reform process. A regional initiative to share experience and build consensus for reform may also be needed.


Supporting New Research Priorities

A large part of Bank loans for agricultural research is used to support priority research areas. These are established by NARSs, increasingly through the use of more systematic and formal priority-setting methods. Such priorities will necessarily be dynamic. For example, as market liberalization continues, there will be growing demand for research on commodities with export potential that will have to address special problems of post-harvest handling and quality standards, including pesticide residues. Bank support will also be dictated by changes in science itself. Four major areas of research for increased Bank support are briefly discussed below.

Linkages to Basic Research

The past decade has produced major changes in the opportunities for agricultural research to

Box 4.4 Global Forum on Agricultural Research

A 1996 meeting of NARSs, Consultative Group on International Agricultural Research (CGIAR) centers, advanced research institutes, NGOs, the private sector, development assistance donors, and farmers organizations developed a Declaration of a Global Forum on Agricultural Research. The Global Forum seeks to bring these various partners together to promote increased partnerships and discussion of major issues affecting international agricultural research. The Global Forum focuses on five goals: (1) enhancing the capacities of NARSs, (2) improving priority setting for international agricultural research, (3) strengthening regional organizations and NARS-NARS partnerships, (4) fostering research partnerships, and (5) mobilizing funding for agricultural research. The forum is scheduled to meet every three years and will operate through a Secretariat, Steering Committee, and electronic forum in the interim. The Global Forum provides an opportunity for NARSs to participate more actively in shaping debates within the global agricultural research system and for developing collaborative linkages.
make use of advances in basic sciences. This is especially true in biotechnology, which is now becoming a reality in farmers' fields in industrialized countries. Only the largest and most mature NARSs will have the resources or capacity to undertake basic research, but all will have to ensure that their farmers have access to the products of this research. Universities often may be important in basic research, especially as they become more fully involved in research in general. However, most NARSs will have to depend on external links with regional, international, and advanced research centers, and with the private sector, to gain access to much of this new technology. Bank projects can facilitate these links by giving support to:

- Funding to facilitate global links and collaborative research programs. Even smaller NARSs are important participants in the more applied end of the basic research spectrum.
- Developing policies and associated legislation on intellectual property rights.
- Developing—with full participation of the public—policies on biosafety and potential risks associated with the release of new transgenic technologies.
- Developing country-specific strategies for biotechnology, including developing local expertise, mechanisms for accessing proprietary technologies, and participation in international networks.
- Support to local capacity building in biotechnology issues, especially biosafety and environmental impact assessment.

Research on Natural Resources Management

Research for a Knowledge-Intensive Agriculture

In all regions a priority will be to strengthen both research (strategic and applied and adaptive) and technology dissemination in the emerging knowledge-intensive agriculture. In high potential areas that have undergone rapid technical change, returns to further intensification are diminishing and future gains will come from using inputs more efficiently. This implies reducing the level of external inputs through developing improved information on site- and season-specific management options (for example, integrated pest, nutrient, and water management). In lower potential areas, where variability in space and time tends to be high, knowledge-intensive approaches are needed at an even earlier stage of technical change.

The move toward knowledge-intensive management will be stimulated by environmental concerns as well as by the need to reduce costs and remain competitive under market liberalization. Developing such knowledge-intensive systems will entail activities, including more basic research on crop-soil-water-nutrient interactions, decentralized adaptive research, use of new information technologies (for example, geographic information systems (GIS) and crop models) (box 4.5), and adaptation of decision aids and information technologies to the needs of small farmers (Byerlee 1997). The appropriate mechanisms to organize and manage research and technology dissemination for knowledge-intensive agriculture is still being debated and the Bank needs to be permanently active in that debate.

Research on Natural Resources Management

With heightened awareness of environmental concerns, strengthening capacity in research on natural resource management is a now a high priority. However, it is important to recognize the complementarity between productivity-enhancing research and research on natural resources management. Commodity research may make important preventative contributions to natural resource management through productivity increases in favored areas that alleviate pressures on marginal areas. However, technology is only one element in the solution of natural resource management and environmental problems. Institutional and policy changes, such as property rights and appropriate price incentives, may be more critical for many natural resource problems.

Bank projects can support research on natural resources management through:

- Encouraging capacity building in selected disciplines, especially soil science, geographic information systems, and social-
Box 4.5 Geographic information systems: A potentially powerful new tool for agricultural research

Geographic information systems (GIS) represent a potentially important new tool for agricultural research to organize and manipulate geographically referenced data. Computer technology and methodologies for GIS technology are evolving rapidly. GIS systems offer the potential to access vast amounts of remote sensing data, manage and integrate large data sets, and develop models to predict changes in defined variables. Agricultural research applications of GIS include:

- Identifying "recommendation domains" or areas for dissemination of new technologies
- Monitoring the spread of new technologies, pest outbreaks, or changing social or environmental conditions
- Serving as a powerful tool for before and after the fact impact assessment of research and new technology.

GIS technology is especially useful for natural resources management applications and can be effective for presenting and explaining data to decision-makers. To be effective, the relatively modest investments in GIS hardware, software, and training must be balanced by appropriate attention to availability of geo-referenced data (UNEP 1997).

Science, which are some of the weakest disciplines in most NARSs.

- Supporting new organizational models to facilitate natural resources management research, which is by nature systems-oriented, multi-disciplinary, and long term research. This does not imply the creation of new institutes focused on natural resources—although this may sometimes be justified—but may require new mechanisms, such as the matrix approach, to bring together required skills from commodity and disciplinary programs within the existing organizational structure (Crosson and Anderson 1993).

- Supporting the involvement of other stakeholders, including government agencies, NGOs, universities, IARCs, and local communities, to resolve resource management problems. This may require greater organizational and wider networking skills than conventional commodity research.

Social Science Research

Many of the issues confronting the NARSs require strong social science input (Byerlee and Franzel 1993). These include: broadening the agenda of NARSs (for example, NRMR), improving efficiency (for example, research priority setting and evaluation), and improving client orientation. Yet social science is one of the weakest disciplines in NARSs, even in relatively strong NARSs.5

This implies either increased staffing of social scientists or increased funding for contracting economic and rural social science research at universities, NGOs, and other institutions outside the NARI. It also requires increased attention to training, both in-country and externally, and strong leadership for social science research at the highest level in NARSs to promote social scientist input into research programs and research management.

Implications for the Bank

While there is a strong case for continued financing of agricultural research, the size and composition of loans in the future is likely to be different. Although good research and technology development require sustained investment, it is more dependent on scientific quality than on money.

Implications for Project Lending

Many of the research system costs that have been financed in the past are now in much less need of Bank financing. These include:

- Construction of new research infrastructure. It is now clear that, for the present,
most NARIs have adequate—or even excess—physical infrastructure. Future strategies have to consider options for reductions in physical plant:

- Financing of operational costs. In the past external funding of operational costs delayed the development of sustainable indigenous funding mechanisms for NARSs. However, operational costs may be necessary and legitimate investments in smaller, poorer NARSs, where there are few alternatives. Even in some of the larger systems, operational cost financing may be justified in the short term to influence research system programs and organization and to shift attention to new research priorities. However, the total volume of operational cost financing should decline over time.

- Foreign training to expand the capacities of scientific and management staff of NARSs, and technical assistance to conduct research in NARSs. System expansion has now slowed, and qualified and capable local staff are now much more available.

Although much of the costly, big-ticket items are less needed now than in the past, there remains some important financing needs for many NARSs, especially in public sector research institutes:

- Equipment and materials—usually including some imported materials—will be continuing needs as NARSs adopt new technologies and equipment and take on new research priorities. Modest funding for equipment can have a substantial impact on the productivity of research systems.

- Facility maintenance and repair will be sorely needed to correct errors of the past in overbuilding and under-maintaining facilities. Upgrading—and in some cases relocating—experimental farms to improve research quality will be important. Such investments should always be conditioned on governmental commitment and capacity to provide adequate funding for future maintenance.

- Investment in information systems is now a necessity to ensure that all scientists have ready access to the Internet and to scientific information and databases, nationally and internationally.

- Foreign training, international exchanges, and technical assistance, at lower levels than in the past, will remain important to keep researchers abreast of advances in science and to develop expertise in new priority research areas.

- The costs of regional research and international collaborative research will need to be incorporated into NARS budgets.

- Investments in local universities to support both research and agricultural science training. The upgrading of human resources in NARSs will be critically dependent on the quality of local undergraduate and graduate teaching programs.

- Financing of management and policy reforms, including building new mechanisms for funding, training in research management, and outside contracting of management expertise for specific areas.

These shifts in project funding toward less costly items, and the critical need to focus on financial sustainability, imply that future Bank projects will be smaller, but more complex and managerially intensive in preparation and supervision. Overall lending to agricultural research may fall (although this depends on lending to countries in Eastern Europe and Central Asia that have, to date, requested little support for agricultural research), but this may not be accompanied by a decrease in Bank staff input, given the complexity of the projects. Since many of the projects will stress drastic institutional change, there is a strong case for piloting certain activities before further expansion.

Financing of sequential projects over a period of 10–20 years is still needed in many regions, especially in Africa. This provides greater stability of funding for NARS programs and sufficient time for institutional development and the completion and realization of the benefits of research. Long-term projects
Strengthening National Agricultural Research Systems may reduce overall lending costs and help maintain current levels of finance for the sub-sector, despite lower annual disbursements.

Bank financing of research is increasingly being included as a component of larger projects, especially projects that combine research and extension and sector investment programs. It is essential that these be monitored carefully, in view of Pritchard's (1990) finding that:

"problems in implementing research components in agricultural and rural development projects were sometimes severe and the limited success of these components is a cause for concern."

In research components of projects particular care is needed to:

- Ensure adequate (that is, relatively high) research management and technical input and consultation on design and supervision
- Include funding for international linkages, technical assistance, and training
- Provide support within a framework that leads to the development of sustainable NARS institutions
- Provide adequate levels of support to make a real impact on research programs.

**Bank Staffing and Project Supervision**

Levels of staff inputs into both design and supervision of agricultural research projects need to be protected, regardless of whether research is supported in free-standing projects or as a component of a larger project. Research and extension projects are staff-intensive because the technical and institutional issues are complex. The level and technical content of supervision can be important to the performance of agricultural research and extension projects (World Bank 1997b). The Bank will need to find ways to maintain direct staff supervision, complemented by external expertise.

With the rapid changes in the subsector, staff must be well supported to maintain effectiveness. The emerging thematic group for agricultural knowledge and information systems is a promising vehicle to improve technical back-stopping and portfolio monitoring. Continued training on research management and policy issues is essential, especially as this relates to the evolution of institutionally pluralistic NARSs and the facilitation of research spill-ins.

**Improving Monitoring and Evaluation**

Monitoring and Evaluation in agricultural research projects requires renewed attention. The development of M&E capacity of research programs in research institutions provides the obvious mechanism for improving the M&E of research supported under Bank projects; that is, there should be no need for a separate M&E system for Bank-supported research. Generally, however, Bank-funded projects will have institutional development objectives additional to the objectives of the research system and that require additional performance indicators. These are often difficult to quantify and measure. Ultimately, of course, successful achievement of research program objectives should be taken as an indicator of the success of institutional changes. However, because of the long time lag, intermediate indicators are needed.

A preliminary set of indicators (annex 3) for research projects has been established for research management, research execution, and research capacity building (World Bank 1995). These indicators are now being implemented in several projects and the Bank should review their application in practice and develop guidelines for best practices in monitoring the performance of research projects.

Most Bank projects are too short to measure impact during the project life cycle. However, in most cases, agricultural research is funded in sequential projects and an ongoing process to measure impacts from research funded in earlier projects is required to provide continuing feedback to research planning and operations.
Knowledge Sharing: Dissemination of Good Practices

The promotion of good practices in agricultural research presents special challenges, as best practice may vary widely across countries, depending on the stage of development of the NARS, the type of agriculture, and the size and political organization of the country. The Bank should continue to develop principles of good practice to guide research project design. The application of those principles will require continuing dialogue both within the Bank and with country partners to identify those practices which are most appropriate to a given situation. Given the complexity of the phenomena under consideration here, any reasonable analysis of good practice must necessarily be multipronged, involving a mix of active participation in relevant project work in the regions, research-like investigations of recent experience around the world, and ongoing interaction with others engaged in analyzing the evolution of agricultural research systems.

Good practice in agricultural research has been evolving rapidly over the past few years. To feed lessons back to future project design, the Bank and others must be able to evaluate and synthesize ongoing experiences with new initiatives, such as competitive grants, research corporations and foundations, farmer financing, and joint ventures with the private sector. Special studies or reviews are needed to develop options for long-standing issues that have bedeviled Bank and other projects. The new priorities should include: providing appropriate incentives to researchers, establishing effective research-extension linkages, monitoring research impacts, developing effective priority-setting mechanisms, and linking NARIs to the private sector and NGOs.

The formation of Bank networks and families can provide the vehicle for both synthesis and dissemination of best practice. A thematic group for agricultural knowledge and information systems is being established across the Bank to bring all operational staff together across regions to discuss and develop initiatives in agricultural research, extension, and education. As with any evolving system, one clear imperative for this thematic group will be to set in place arrangements for systematically tracking change and for monitoring new developments.

The dissemination of good practice results within and across NARSs is critical, especially in building borrower commitment to institutional and policy changes. A variety of mechanisms, including case studies, study tours, and regional seminars, are needed to promote these activities. Since seeing is believing, the use of study tours should be more widely encouraged so that staff may visit research systems in other developing and industrialized countries, where specific aspects are regarded as models of best practice.

The Bank is unlikely to have all the required skills in-house to evaluate and apply best practices. The research group will need to develop mechanisms for regularly interacting with others, such as the International Service for National Agricultural Research (ISNAR), actively engaged in agricultural research policy and management. Partnerships, especially those that access private sector experience, may provide new perspectives and be particularly beneficial in technology system development.

Notes

1. One example is United States assistance to NARS development programs, which fell by 71 percent from 1985 to 1996 (Alex 1996).
3. SPAAR has promoted the development of Frameworks for Action (FFAs). These are comprehensive regional action plans for improving NARS operations. Common elements or principles of the FFAs include: developing country research strategies, developing sustainable financing systems, improving NARS management capacities, establishing country research advisory groups, improving research-extension-farmer linkages,

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7. Common elements or principles of the FFAs include:
   - Developing country research strategies.
   - Developing sustainable financing systems.
   - Improving NARS management capacities.
   - Establishing country research advisory groups.
   - Improving research-extension-farmer linkages.

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and facilitating regional research spill-ins (Spurling and others 1992; Weijenberg and others 1993; Weijenberg and others 1995).

4. Although this principle is sound, developing institutional and financial sustainability for many research institutions will be a long-term objective. There will often be, as in Africa, a need to support interim steps for establishing sustainable capacities.

5. Explanations for this widespread situation include historical lack of emphasis on social-science training within aid programs and strong job-market competition from the private sector and international assistance agencies.

6. Such investments will confront some of the same limitations in financing need as for the NARS as a whole. Emphasis in university development programs must be on training students oriented to employment in private sector occupations or a pluralistic NARS and not traditional training, which emphasized preparation for future government service.

7. A new World Bank Group initiative to improve staff professional development organizes staff in networks, families, and thematic teams. An Agricultural Knowledge and Information Systems Thematic Team is being formed in the Rural Development Family of the Environmentally and Socially Sustainable Development Network.
Annexes
# Main Recommendations from Reviews of World Bank Research Projects

## Increasing resources for research

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<tr>
<td>Mobilizing donor funds</td>
<td>Lead an international effort to mobilize resources for agricultural research</td>
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<td>Ensure consideration of agricultural research in international forums</td>
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<td>Bank lending for research</td>
<td>Increase Bank lending for research projects</td>
<td>Continue Bank lending to develop strong NARSs</td>
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<tr>
<td>Financing operating costs</td>
<td>Provide financing of incremental operating costs, as needed</td>
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<td>Finance NARS operating costs only when borrowers demonstrate commitment to research agenda</td>
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<td>Consideration of research in country dialog</td>
<td>Provide fuller treatment of agricultural research issues in sector studies and policy dialog</td>
<td>Define research linkages to country's overall agricultural development in project analyses</td>
<td></td>
<td>Include consideration of agricultural research issues in CAS and in policy dialogue with borrowers</td>
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<td>Government commitment to research funding</td>
<td>Require government commitment to research and funding of research system</td>
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<td>Require demonstration of borrower commitment to research</td>
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<td>Public awareness of research impacts</td>
<td>Expand analysis and evaluation of research projects to consider research impacts on employment and nutrition</td>
<td>Assist NARSs to develop public awareness programs on value of research, and support publication of research results and accomplishments</td>
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<tr>
<td>Diversification of funding for NARSs</td>
<td>Explore alternative funding mechanisms for providing operating funding for research</td>
<td>Encourage research cost recovery initiatives in NARSs</td>
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<td>Improve research system efficiency and quality of research</td>
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<td>Training for NARS staff</td>
<td>Expand training programs to strengthen administrative and technical capacities of NARSs and tailor training to ensure that staff return to NARSs</td>
<td>Define research staffing needs and provide adequate training to meet those needs</td>
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<td></td>
<td>Emphasize training, especially for research program leaders</td>
<td>Emphasize needs-based training and technical assistance</td>
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<td>Incentives for researchers</td>
<td>Provide improved incentives and terms of service for research scientists</td>
<td>Provide incentives for retention of high-quality staff within NARSs</td>
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<td></td>
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<td>Insist on performance incentives for NARS staff</td>
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<td>Long-term research program support</td>
<td>Provide longer-term (10–15-year) support to NARSs</td>
<td>Expand time frame of research projects</td>
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<td>Monitoring and evaluation systems</td>
<td>Assist NARSs to establish monitoring and evaluation systems</td>
<td>Emphasize monitoring and evaluation and socioeconomic analysis within NARSs</td>
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<td>Research and experiment station management</td>
<td>Provide training in research management and experiment station management</td>
<td>Support improvements in the management of research facilities</td>
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<td></td>
<td>Emphasize support for research management and experiment station management</td>
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<td>Input to quality of research</td>
<td>Increase supervision and evaluation of research projects, including annual workshops, progress reviews, and external reviews</td>
<td>Improve supervision of technical quality of research and of institutional changes in NARSs</td>
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<td>Emphasize routine internal and external review of research programs</td>
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<td>University development</td>
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<td></td>
<td>Strengthen graduate teaching and research at developing country universities</td>
<td>Consider research-education sector linkages and their importance for research and training</td>
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<td>Strengthen university capacity for research and teaching</td>
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<tr>
<td>Other issues</td>
<td>For small countries, develop capacity for adaptive research on small number of crops</td>
<td>Increase assessment of sociopolitical and cultural factors and increase borrower participation in project design</td>
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<td></td>
<td>Provide support for more basic and strategic research</td>
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<td>As appropriate, rationalize existing facilities and resources rather than expanding system</td>
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<td>Encourage increase in NARS operating funding in relation to salary costs</td>
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Main Recommendations from Reviews of World Bank Research Projects (continued)

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<tr>
<td>Improving research priority setting and client orientation</td>
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<tr>
<td>National agricultural research plans</td>
<td>Require development of an overall strategy for national research systems</td>
<td></td>
<td>Encourage development of national agricultural research plans</td>
<td>Continue to promote research master plans, but with greater national ownership of plans</td>
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<td>Applied and adaptive research</td>
<td>Target applied and adaptive research directly applicable to farmers’ problems</td>
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<td>Support adaptive and applied research for the whole farming system</td>
<td>Require formulation of a client-responsive research plan as part of project preparation</td>
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<td>Research on natural resources conservation and the environment</td>
<td>Support research on conserving productivity of natural resources and on environmental consequences of high input production systems</td>
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<td>Farming systems approach</td>
<td>Require a farmer-oriented philosophy using FSR, commodity, and multidisciplinary teams for adaptive research on farmers’ problems</td>
<td>Emphasize research aimed at the whole farm</td>
<td>Emphasize client-responsive research through FSR, on-farm research, and stakeholder involvement in research planning</td>
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<tr>
<td>Other issues</td>
<td>• Target research on food crops for small farmers and the poor and on nutrition and food system impacts of research • Target farming systems research on neglected or resource-poor areas</td>
<td>Emphasize research for low-potential areas</td>
<td>Emphasize ex ante economic evaluation and use of research performance indicators Provide guidance on user involvement in research design and evaluation</td>
<td>Increase client involvement in research planning and implementation.</td>
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<td>Improving mechanisms for technology transfer</td>
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<tr>
<td>Research-extension linkages</td>
<td>Strengthen research-extension linkages by combining within a single agency</td>
<td>Review concepts and procedures for research-extension linkages and develop operational guidelines</td>
<td>Consider technology generation, acquisition, and adaptation as an integral system</td>
<td>Increase integration of research and extension.</td>
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<td>Policy environment for technology adoption</td>
<td>Require borrower adoption of policies conducive to generation and adoption of efficient technology</td>
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### Improving linkages with the global agricultural research system

<table>
<thead>
<tr>
<th>Support to CGIAR NARS-IARC linkages</th>
<th>Continue support to IARCs Link NARSs research work with the IARC programs</th>
<th>Take maximum advantage of NARS linkages to IARCs</th>
<th>Use Bank influence to increase IARC support for research with NARSs under Bank projects</th>
<th>Continue support to CGIAR Facilitate NARS linkages to IARCs and other research entities</th>
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<tbody>
<tr>
<td>Regional initiatives</td>
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<td>Policy environment for private</td>
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<td>sector research</td>
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### Improving Bank support to agricultural research system development

<table>
<thead>
<tr>
<th>Specialized Bank staff</th>
<th>Increase the number of specialized Bank staff</th>
<th>Train Bank staff in supervision and appraisal of research projects</th>
<th>Establish core of specialized research staff</th>
<th>Establish core staff to enhance quality of agricultural research projects and provide specialized training relevant to agricultural research projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portfolio review</td>
<td></td>
<td>Examine causes for lack of effectiveness of research components of projects and evaluate effectiveness of policy-based lending for development of research capacities</td>
<td>Provide support for procurement at beginning of projects</td>
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<td>Project start-up</td>
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<tr>
<td>Other issues</td>
<td>Expand EDI course materials on the management, organization, and development potential of research</td>
<td>• Determine Bank policy with regard to biotechnology research • Evaluate the contribution of long- and short-term consultants to research projects</td>
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</table>

Note: Reviews are in World Bank (1980, 1983, 1997a), Pritchard (1990), and Purcell and Anderson (1997).
## Annex 2

### World Bank Funding for Agricultural Research by Year and by Geographic Region

<table>
<thead>
<tr>
<th>Year</th>
<th>South Asia</th>
<th>Africa</th>
<th>Latin America and the Caribbean</th>
<th>Middle East and North Africa</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total projects with research</td>
<td>Full research projects</td>
<td>Research funding (US$million)</td>
<td>Total projects with research</td>
</tr>
<tr>
<td>1981</td>
<td>6</td>
<td>1</td>
<td>27.75</td>
<td>14</td>
</tr>
<tr>
<td>1982</td>
<td>4</td>
<td>0</td>
<td>10.25</td>
<td>8</td>
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<tr>
<td>1983</td>
<td>12</td>
<td>0</td>
<td>10.50</td>
<td>13</td>
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<tr>
<td>1984</td>
<td>6</td>
<td>1</td>
<td>23.20</td>
<td>12</td>
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<tr>
<td>1985</td>
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Source: ESDAR database on World Bank research projects.
Illustrative Project Performance Indicators for Agricultural Research Projects

Project performance and impact are measured by indicators, which provide direct or indirect measurement of program progress. Project performance indicators are now required for all Bank projects. Objectively quantifiable indicators are desirable, but it is often not possible to quantify program outcomes and qualitative or subjectively measured indicators may have to be used. Performance indicators are broken out in a cause-and-effect hierarchy including:

- Impact indicators to measure development progress and impact of the project on desired social goals
- Project outcome indicators to measure results directly attributable to the project
- Project output indicators to measure direct "products" of the project
- Project implementation indicators to measure inputs to project activities.

These performance indicators essentially measure performance at two major levels: process indicators that measure the inputs and outputs of research and are closely related to research program activities and impact indicators that reflect the development impacts of research on national policy objectives.

Process indicators typically include measures of input usage (input indicators), such as funds expended, technical assistance provided, scientist and staff time used, equipment purchased, and training completed. The second level of process indicators is that of measuring direct project activity accomplishments (output indicators), such as trials conducted, technologies developed or released, buildings constructed, research plans completed, staff trained in an agency, and laboratories equipped.

Indicators of project impacts are more difficult to measure as these are less directly connected with project activity. A first level includes outcome indicators (or intermediate impact indicators or intermediate result indicators). These measure changes that are fairly direct results of the project and may include: technology adoption rates, measures of productivity of research institutions, and measures of the quality of research work. Changes in outcome indicators should be expected to be measurable within a project lifetime. Impact indicators relate to the effects of the project on national social and economic objectives, such as productivity, poverty alleviation, and natural resource conservation. As the time lag for achieving these impacts is great and attribution of cause and effect between a project and the indicators is difficult, there is considerable debate as to whether and how these can be measured and related to individual projects. These are, however, important in that such impacts provide the rationale needed by those concerned with funding research investments.
In designing a project performance monitoring system, it is important to keep the system practical and relatively simple, with limited numbers of performance indicators to be tracked in any particular project. A preliminary checklist of potential indicators has been established for projects relating to research management, research execution, and research capacity building (table 3A.1). This list and systems for monitoring project performance will need revision in response to further Bank experience and determination of best practice.
### Table 3A.1 Potential project performance indicators for research projects

<table>
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<tr>
<th>Indicator level/type</th>
<th>Research management components</th>
<th>Research program implementation components</th>
<th>Research infrastructure and human resources component</th>
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</table>
| Social and economic impact | To the extent that they can be associated with agricultural technology:  
- Increased factor productivity  
- Social rate of return to research investment  
- Trends in environmental indicators  
- Reduction in poverty  
- Improved nutrition | To the extent that they can be associated with agricultural technology:  
- Increased factor productivity  
- Social rate of return to research investment  
- Trends in environmental indicators  
- Reduction in poverty  
- Improved nutrition | To the extent that they can be associated with agricultural technology:  
- Increased factor productivity  
- Social rate of return to research investment  
- Trends in environmental indicators  
- Reduction in poverty  
- Improved nutrition |
| Project outcomes | Objective measures:  
- Trends in recurrent costs relative to total budget  
- Resource allocation shifts toward established priorities  
- Share of private financing of total research expenditure  
- Share of budget of public sector self-generated  
- Number of joint ventures with the private sector  
- Percentage of budget allocated through competitive grants  
- Ratio of professional to support staff  
- Share of contracted research | Objective measures:  
- Adoption of released technologies and management recommendations  
- Benefits of adoption of new technologies  
- Adoption of resource conservation technologies | Objective measures:  
- Number of peer-reviewed publications a year per researcher  
- Trained technicians per scientist  
- Research staff turnover rate  
- Proportion of laboratories equipped and functioning |
| Project outputs | Objective measures:  
- Research plans established  
- Research plans financed  
- Peer-review mechanisms in place | Objective measures:  
- New varieties released  
- Extension recommendations published  
- Number and type of early adopting farmers and estimated productivity impacts | Objective measures:  
- Number of researchers trained  
- Number of female researchers trained  
- Degrees awarded |
- Monitoring and evaluation systems established, including management information systems
- Staff performance appraisal and promotion system revamped to reward productivity
- Policy unit established
- Changes in orientation of research (multidisciplinary, multi-institutional)

Subjective measures:
- External management reviews
- Quality of research-extension linkages
- Adequacy of regulatory and legal frameworks for research and research organizations
- Adequacy of financial accounting procedures
- Evidence of feedback from M&E system to research and management decisions
- Degree of research networking

Objective measures:
- Participatory forums established
- Training and technical assistance requirements identified and contracted
- On-time flow of funds to research units
- On-time reporting of expenditures
- Annual research reports produced

Subjective measures:
- Quality of contacts with stakeholders
- Stakeholders' satisfaction with research system

Objective measures:
- Other research products, completed research tools/methods developed
- Papers published
- Number of collaborative research programs established with national and international partners
- Laboratories built
- Journals/publications acquired
- Trainees' assessed job performance before and after training
- Percentage of scientists linked to electronic information systems

Subjective measures:
- Improved knowledge of farming systems
- Improved knowledge of natural resources status and trends
- Improved research relevance through use of on-farm participatory methods
- Number of collaborative research programs after training
- Number of trainees expressing satisfaction with training
- Trainees' job performance
- Quality of training
- Quality of civil works

Objective measures:
- Timely provision of funds, equipment, and staff time to process
- Number of proposals processed and average time to process
- Implementation according to milestones established for each research project and program
- Proportion of researcher time in field or laboratory
- Completion of diagnostic reports on farmer constraints and priorities
- Meetings of researchers and clients
- Completion of scientific program reviews, including external reviews

Subjective measures:
- Degree of farmer participation in research assessments
- Farmer assessment of research process quality of information and dialogue between researchers and clients
- Meetings of researchers with clients

Bibliography


FAO (U.N. Food and Agriculture Organization). 1996. "Role of Research in Global Food Security and Agri-


